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High Temperature Composite Analyzer (HITCAN) User's Manual
Version 1.0

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ABSTRACT

This manual describes "how to use" the computer code, HITCAN (HIgh Temperature Composite ANalyzer). HITCAN is a general purpose computer program for predicting nonlinear global structural and local stress-strain response of arbitrarily oriented, multilayered high temperature metal matrix composite structures. This code combines composite mechanics and laminate theory with an internal data base for material properties of the constituents (matrix, fiber and interphase). The thermo-mechanical properties of the constituents are considered to be nonlinearly dependent on several parameters including temperature, stress and stress rate. The computation procedure for the analysis of the composite structures uses the finite element method. HITCAN is written in FORTRAN 77 computer language and at present has been configured and executed on the NASA Lewis Research Center CRAY XMP and YMP computers.

This manual describes HITCAN's capabilities and limitations followed by input/execution/output descriptions and example problems. The input is described in detail including (1) geometry modeling, (2) types of finite elements, (3) types of analysis, (4) material data, (5) types of loading, (6) boundary conditions, (7) output control, (8) program options, and (9) data bank.

CHAPTER 1

INTRODUCTION

The potential use of High Temperature Metal Matrix Composite (HTMMC) materials in propulsion systems has already been recognized. The advantages of HTMMC materials are high operational temperatures, high specific moduli and strengths, tailorable properties, dimensional stability, and hygral resistance. The thermo-mechanical properties of components made from HTMMC materials exhibit a nonlinear dependence on parameters such as temperature, stress, and stress rate. Since comprehensive experimental investigations are prohibitive in cost, it is advantageous to have computational schemes which can simulate the nonlinear response of components made from HTMMC materials.

Research related to various aspects of HTMMC materials and structures has been conducted at NASA Lewis Research Center (LeRC) for several years. This work has focused on high temperature material behavior, constitutive law development, MMC experimental mechanics, mathematical modeling, and nonlinear structural analysis and simulation. Building upon this research effort, a HIgh Temperature Composites ANalyzer (HITCAN), has been developed.

HITCAN is a general purpose computer program for predicting global structural and local stress-strain response of arbitrarily oriented, multilayered high temperature metal matrix composite structures both at the constituent (fiber, matrix, and interphase) and the structural level. The thermo-mechanical properties of the constituent materials are considered to be nonlinearly dependent on several parameters including temperature, stress, and stress rate. The computational procedure uses the finite element method, which employs an incremental direct iteration procedure to solve the nonlinear equations. A schematic of this approach is shown in Figure 1.1.

HITCAN includes:

- a dedicated mesh generator, adapted from COBSTRAN (Reference 1);
- capability for simulating nonlinear behavior at all levels of composite material, adapted from METCAN (Reference. 2);
- finite element structural analysis, adapted from MHOST (Reference 3).

All three computer programs, COBSTRAN, METCAN, and MHOST were developed in-house at NASA and are used as modules. This makes HITCAN a modular stand-alone code, independent of commercial codes.

HITCAN, written in the FORTRAN 77 language, has been configured and executed on the LeRC CRAY XMP and YMP computer systems. The code is made up of approximately 16,000 lines. The companion codes residing in the HITCAN library, COBSTRAN, METCAN, and MHOST consist of approximately 7000, 10000, and 51000 lines, respectively.

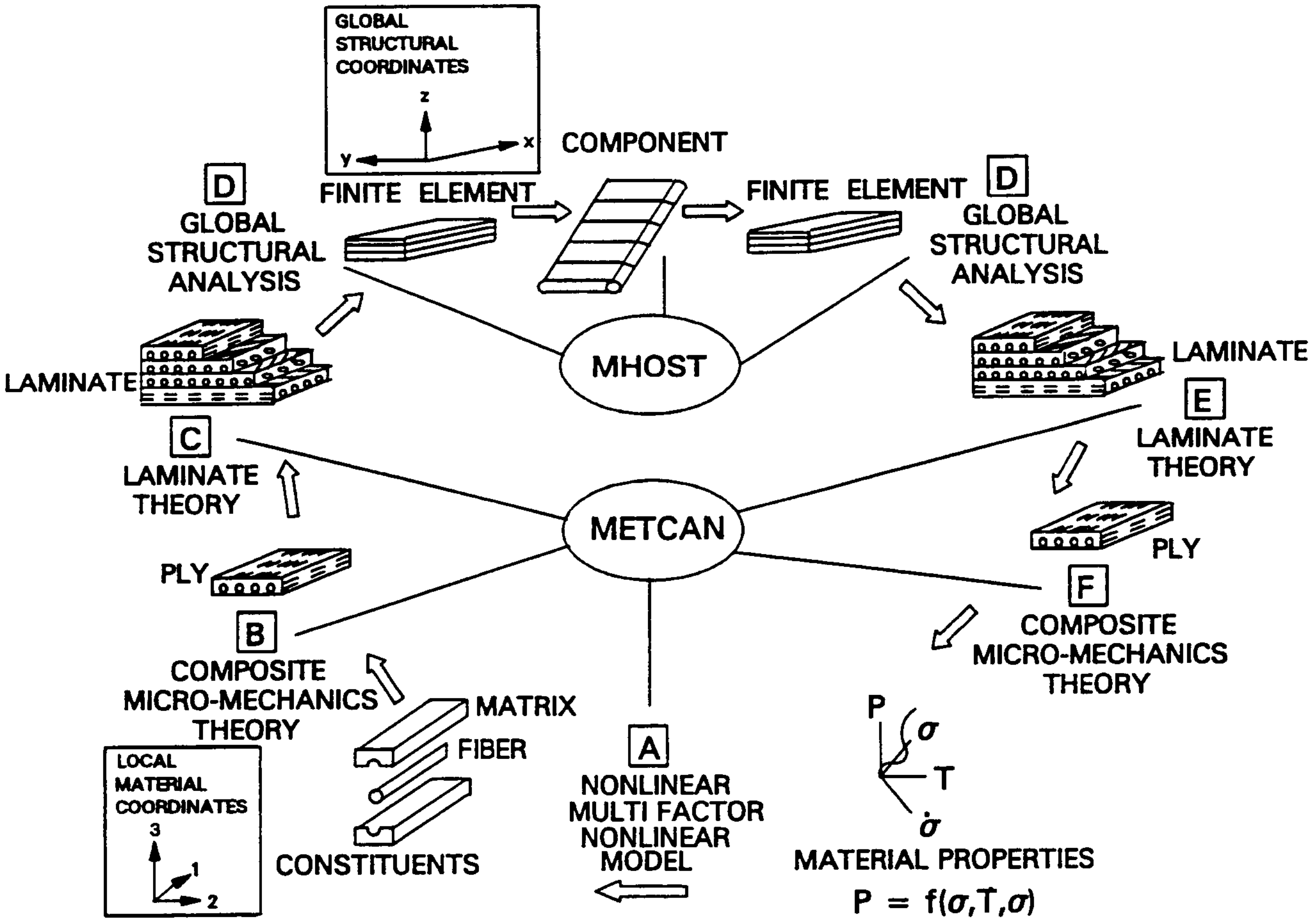

Figure 1.1: HITCAN: An Integrated Approach for High Temperature Composite Structural Analysis

After a brief description of the capabilities and limitations in the HITCAN computer code, a step-by-step outline of the procedure necessary to utilize HITCAN, i. e., the preparation of the input data and the creation of a databank of constituent material properties and parameters, is given. Chapter 3 describes the input data file preparation. The shell scripts which are required to compile and run HITCAN on the CRAY X-MP and Y-MP are described in Chapter 4. A description of the output is given in Chapter 5. Finally, in Chapter 6, the input for three example problems is explained.

The potential user of HITCAN is reminded that the program is in a state of on-going development and the methodology which HITCAN comprises is of an evolutionary nature.

The structure of the input/output file structures in HITCAN is shown in Figure 1.2.

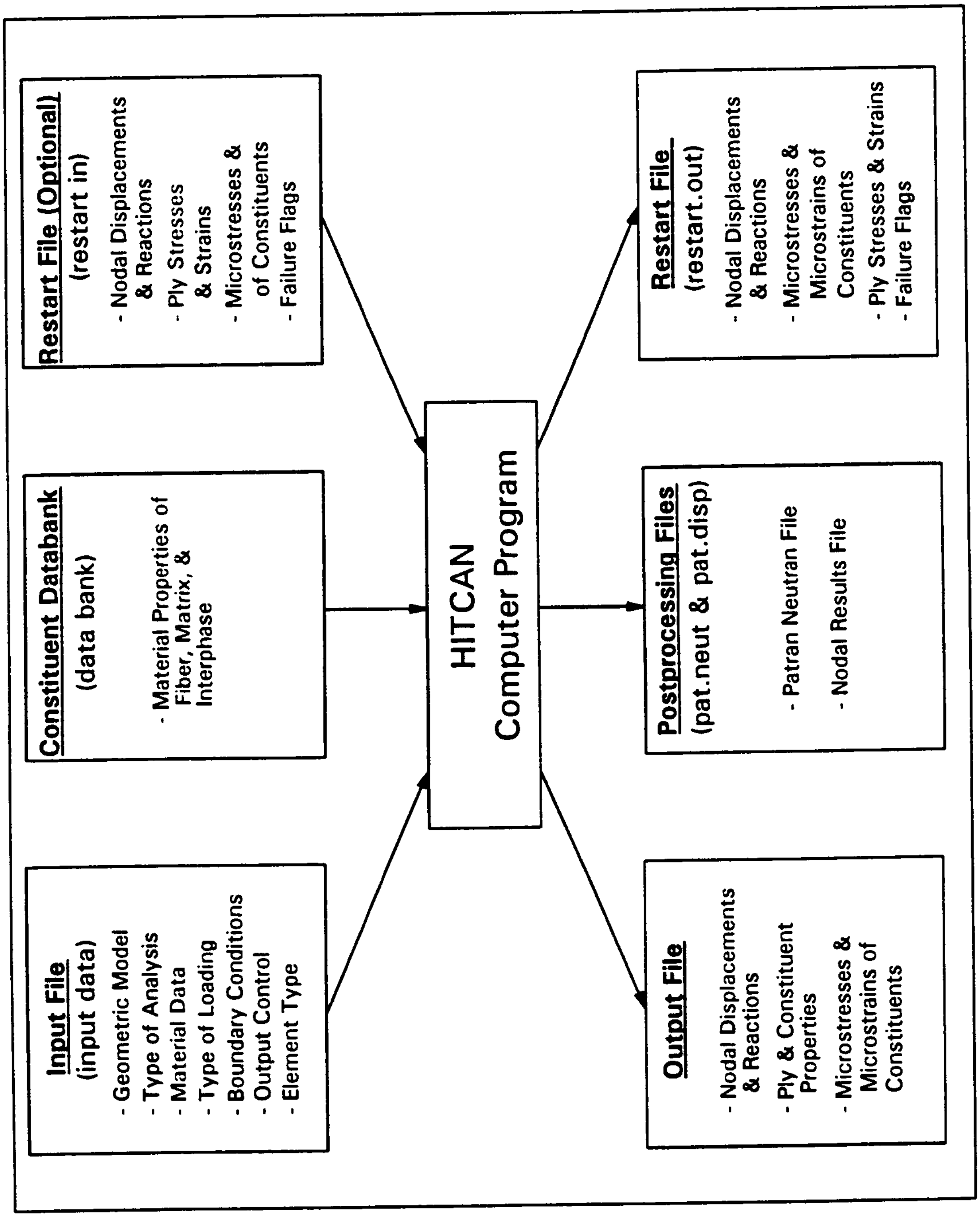

Figure 1.2: HITCAN/Input/Output File Structure

CHAPTER 2

CAPABILITIES AND LIMITATIONS

HITCAN is capable of predicting global structural and local stress-strain response of multilayered HTMMC structures exhibiting nonlinear material behavior. Each layer of the composite can be constructed of different materials and can be arbitrarily oriented. The constitutive model employed in METCAN is specifically designed for HTMMC, therefore it is recommended that HITCAN be used only for metal matrix composites.

The current version of the code is based on a rectilinear coordinate system. Arbitrary shaped geometries can be modeled using interpolators included in the mesh generation module of the code.

At the present time, the following analyses are available in HITCAN:

- Incremental static analysis with nonlinear anisotropic material behavior
- Dynamic analysis using direct time integration
- Modal analysis (free vibration)
- Buckling analysis (first critical buckling load)

The element library includes 3 four-noded elements, i.e. plate, plane stress, and plane strain, and 1 eight noded element, i.e. a 3D solid. The current mesh generation capability of the code allows modeling of solid structures using any of the 4 types of elements. The user may also input a finite element model directly. The code is capable of handling a variety of boundary conditions, loadings (centrifugal, concentrated, distributed, pressure, temperature, static, transient, cyclic, and impact), and various types of structures (such as beam, plate, ring, curved panel, and built-up structures). A list of HITCAN's analysis capabilities can be found in Table 2.1.

The limitations of the code are :

- Formulation assumes small displacement and small strain theory;
- Elements of different types cannot be combined;
- Hollow structures can be modeled using the plate element only;
- The finite element model generated by HITCAN can have a nonuniform mesh only along the x-axis;
- If the curvature is large, the mesh will not be uniform.

HITCAN presents analysis results at the global, laminate, and ply levels. Results include displacements, reactions, stresses, and modes shapes. The code also has the capability to generate post-processing files for PATRAN.

Type of Analysis ↓ / Type of Element →	Plate	Plane Strain	Plane Stress	8-Node Solid
Static	tested	-	-	tested
Buckling (a)	tested	-	-	-
Load Stepping	tested	-	-	tested
Modal (Natural Vibration Modes) (b)	tested	-	-	-
Time-domain	-	-	-	-
Loading				
Mechanical	tested			tested
Thermal	tested			tested
Cyclic	-	-	-	-
Impact	-	-	-	-
Constitutive Models (c)				
$P = \text{Constant}$	tested	-	-	tested
$P = f(T)$ (temperature dependence)	tested	-	-	tested
$P = f(\sigma)$ (stress dependence)	tested	-	-	tested
$P = f(\sigma)$ (stress rate dependence)	tested	-	-	tested
$P = f(t)$ (creep)	-	-	-	-
$P = f(T\dot{\sigma}, \sigma, \sigma)$ (combination)	tested	-	-	tested
$P = f(T\sigma, \dot{\sigma}, \sigma, t)$ (creep combination)	-	-	-	-
Fiber Degradation	tested	-	-	tested
Fabrication-induced Stresses	tested	-	-	tested
Ply Orientations				
Arbitrary	tested	-	-	tested

(a) Tested 1 buckling mode
(b) Tested 4 vibration modes

(c) Constitutive models: Notation
P: Material properties
T: Temperature
σ: Stress
$\dot{\sigma}$: Stress rate
t: Time

Table 2.1: HITCAN Capabilities for Composite Materials

CHAPTER 3

INPUT FORMAT

A single HITCAN input file includes all the data necessary for the selection of analysis options, parameters, mesh generation, composite material type and construction, loading, initial conditions, boundary conditions, and print options. However, the values of material properties at the constituent (fiber, matrix, and interphase) level are not entered in the HITCAN input file, they reside in a separate file, labeled "data bank". This file contains material property data for each of the composite systems used in the analysis. Each composite system is identified with a material name which is entered in the HITCAN input file. The user can edit the "data bank" file to define material property data for any material required. Additional information on the "data bank" file can be found in Section 3.8.

The input file consists of two blocks. The first block contains the title and the program option cards. The second block consists of card groups. Figure 3.1 illustrates the two blocks. The program option cards either control the flow through the program or activate various card groups. There are twenty-eight program option cards, four of these control the flow through the program. They are HPLATE, S3DSOLID, and SPLATE option cards which set the type of finite element model to be generated by HITCAN, and the READ IN MODEL option which enables the user to input into HITCAN a finite element model consisting of eight node solid elements. One of these four cards must be included in the "Program Option Cards" block of the input deck. If the program option card HPLATE is specified then the following program option cards must be included in the input file

PLATE
PLYORDER
ENDOPTION

If SPLATE is used, the program option cards required in the input file are

PLATE or STRESS or STRAIN
PLYORDER
ENDOPTION

When the S3DSOLID is specified, then

BRICK
PLYORDER
ENDOPTION

must be used.

To separate the two blocks the ENDOPTION card is used. This program option card is placed at the end of the "Program Option Cards", as shown in Figure 3.1.

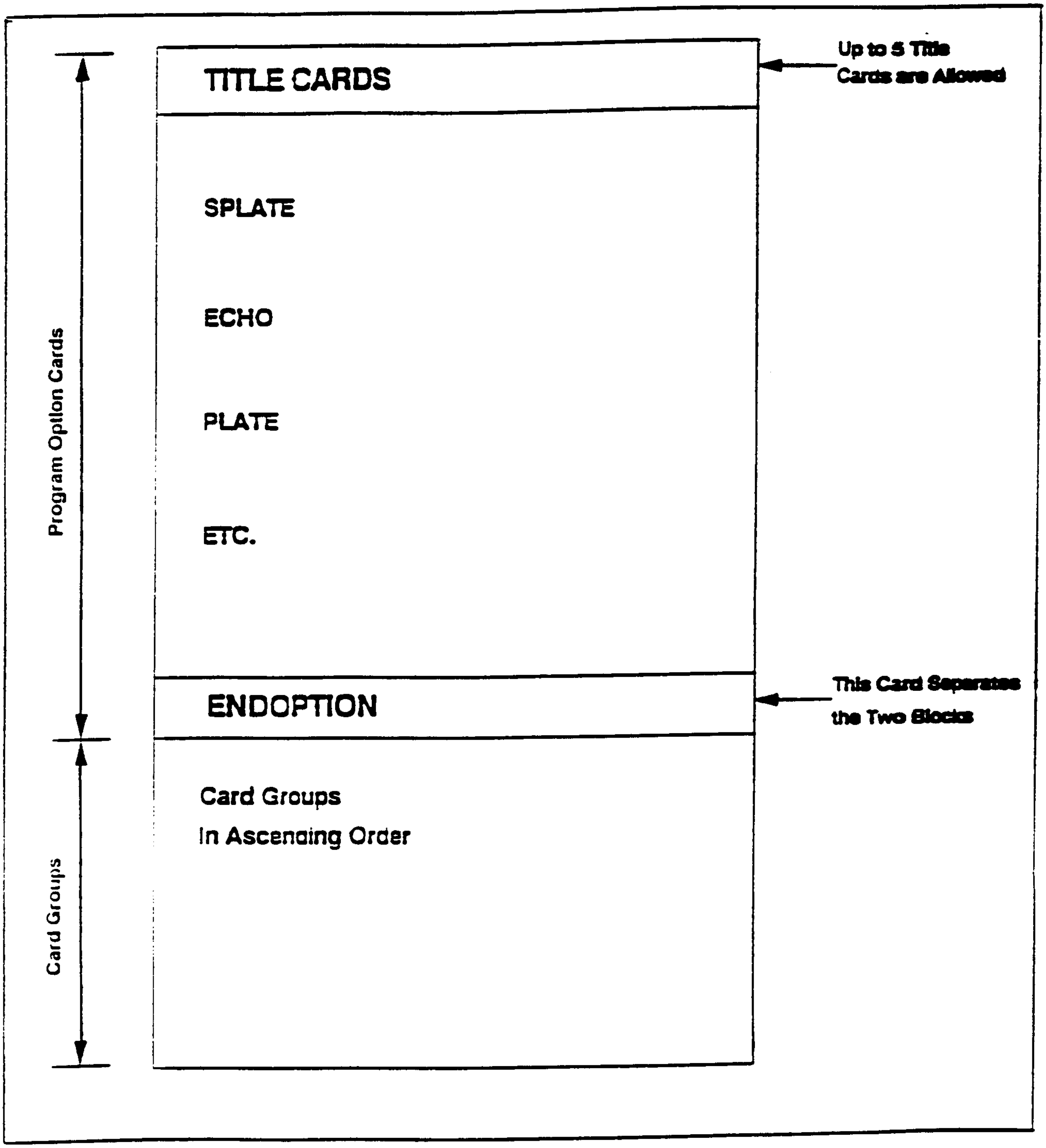

Figure 3.1: Organization of Input File in HITCAN

A card group is a set of one or more cards. Some of the card groups are dependent on either a program option card being specified or a parameter defined in a previous card group. These optional card groups and their respective dependencies are explained within each card group in Section 3.3. If an optional card group is not activated by a previous program option card or user selected parameter, the optional card group must not be included in the input file. The input file should, however, be maintained in numerical order by card group number.

The input file can be broken into 7 functions. These are shown in Figure 3.2. In sections 3.1 to 3.7, the program option cards and card groups used in each one of these functions will be described. By depicting the input file in this manner, the user can quickly assemble an input file. In section 3.9 a summary of all the program option cards is given.

Note that in both the input file and the "data bank" file English units are required.

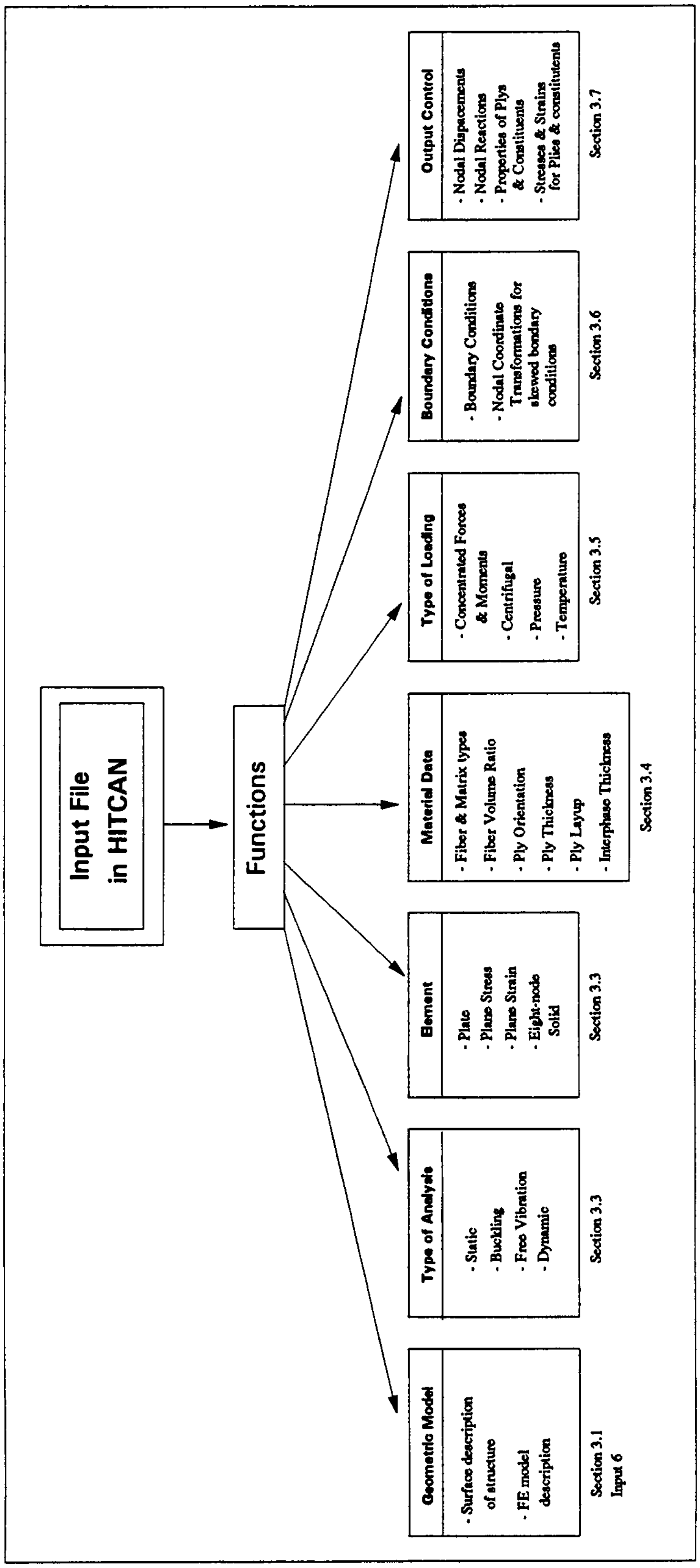

Figure 3.2: Input File Functions

3.1 GEOMETRIC MODELING

HITCAN generates a finite element mesh of the structure, based on coordinates of a few representative points. This is accomplished by interpolating nodal values of geometrical coordinates using a cubic spline. The interpolating function requires that the surface geometry be represented by a continuous and single-valued function. Although HITCAN is a stand-alone computer program, it does create a PATRAN neutral file, so that the user can view the mesh generated. Figure 3.3 shows the different types of structures that can be modeled by HITCAN. There are 3 distinct mesh generation schemes in HITCAN, as categorized below. Any 1 of the 3 mesh generation schemes is activated by choosing the appropriate program option card, shown in the parentheses below.

(1) For solid structures: use plate, plane stress, or plane strain element (SPLATE).
(2) For hollow structures (panel structure): use plate element (HPLATE).
(3) For solid structures: use 3D solid element (S3DSOLID).

The coordinate system must be rectilinear and right-handed. The center of the coordinate system can be placed anywhere. However, in choosing the directions of the three axes, the user should keep it in mind that the mesh can be nonuniform only along the x-axis.

Also, HITCAN provides the user with the ability to enter a finite element model created by a program other than HITCAN. At the present time, this option can only be used with the eight-node solid element. This option can be activated with the program option card READ IN MODEL.

The following table summarizes the different mesh generation schemes and their program option cards and card groups.

TYPE OF STRUCTURE	PROGRAM OPTION CARD	CARD GROUPS
Solid structure using plane stress, plane strain, or plate element	SPLATE	5 27
Hollow structures	HPLATE	2 9 24
Solid structures using eight-node solid element	S3DSOLID	4 26
Read in a finite element model	READ IN MODEL	3 25

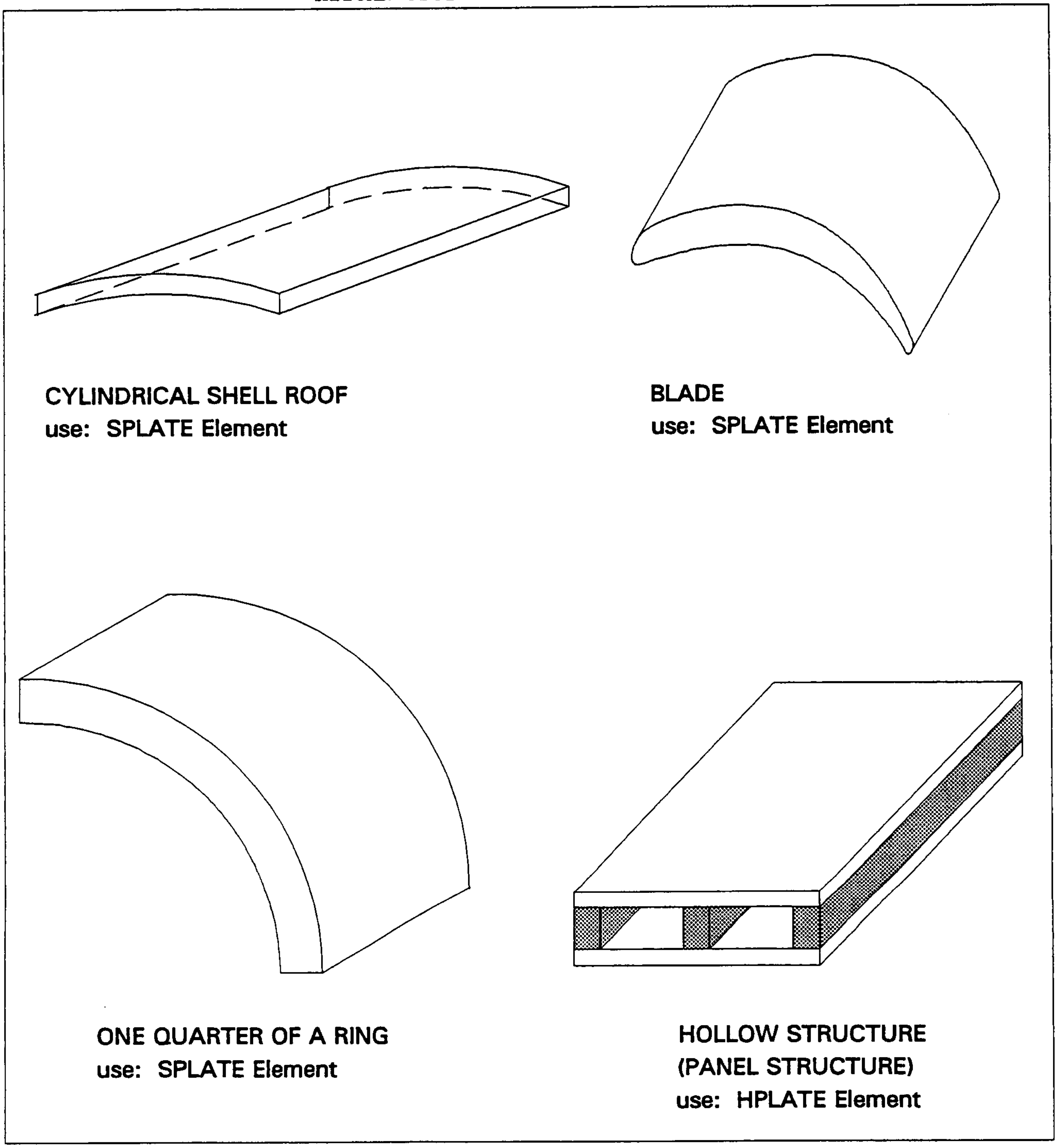

Figure 3.3: Typical Structures That Can Be Modeled Using HITCAN

SPLATE MODEL OPTION

The SPLATE model option allows modeling of structures with arbitrary shapes in x and y directions, but a through-the-thickness plate type shape in the z-direction. An example of the type of structure that can be model with HITCAN is a solid curved panel shown in Figure 3.4. The finite element mesh is generated in the following 4 steps.

Step 1: A right-handed rectilinear coordinate system (x,y,z) is defined, placing the center of the coordinate system at a convenient point.

Step 2: To obtain the surface geometry of a structure, it must be divided into several (y,z) sections along the x-axis. The number of cross sections selected along the x-axis depends upon the curvature of the structure along the x-axis. The mesh generator can fit any curve up to a third degree polymonial, using a cubic spline. Hence, the x-axis must be divided into enough sections such that each section can be modeled using a cubic spline.

Step 3: Each (y,z) cross section along the x-axis consists of a set of points. The number of (y,z) points needed to define a specific cross section are selected so that the curve between the two adjacent points can be modeled using a cubic spline interpolator. A different number of (y,z) points can be selected for different cross sections, along the x-axis.

Step 4: Once the structure is divided into cross sections,along the x-axis in steps 2 and 3 above, the user has already created a coarse finite element mesh. To further subdivide the x and (y,z) sections for obtaining the desired number of elements, the user needs only to input the number of intermediate nodes. The nodal coordinates for the intermediate nodes of the finite element mesh are automatically interpolated.

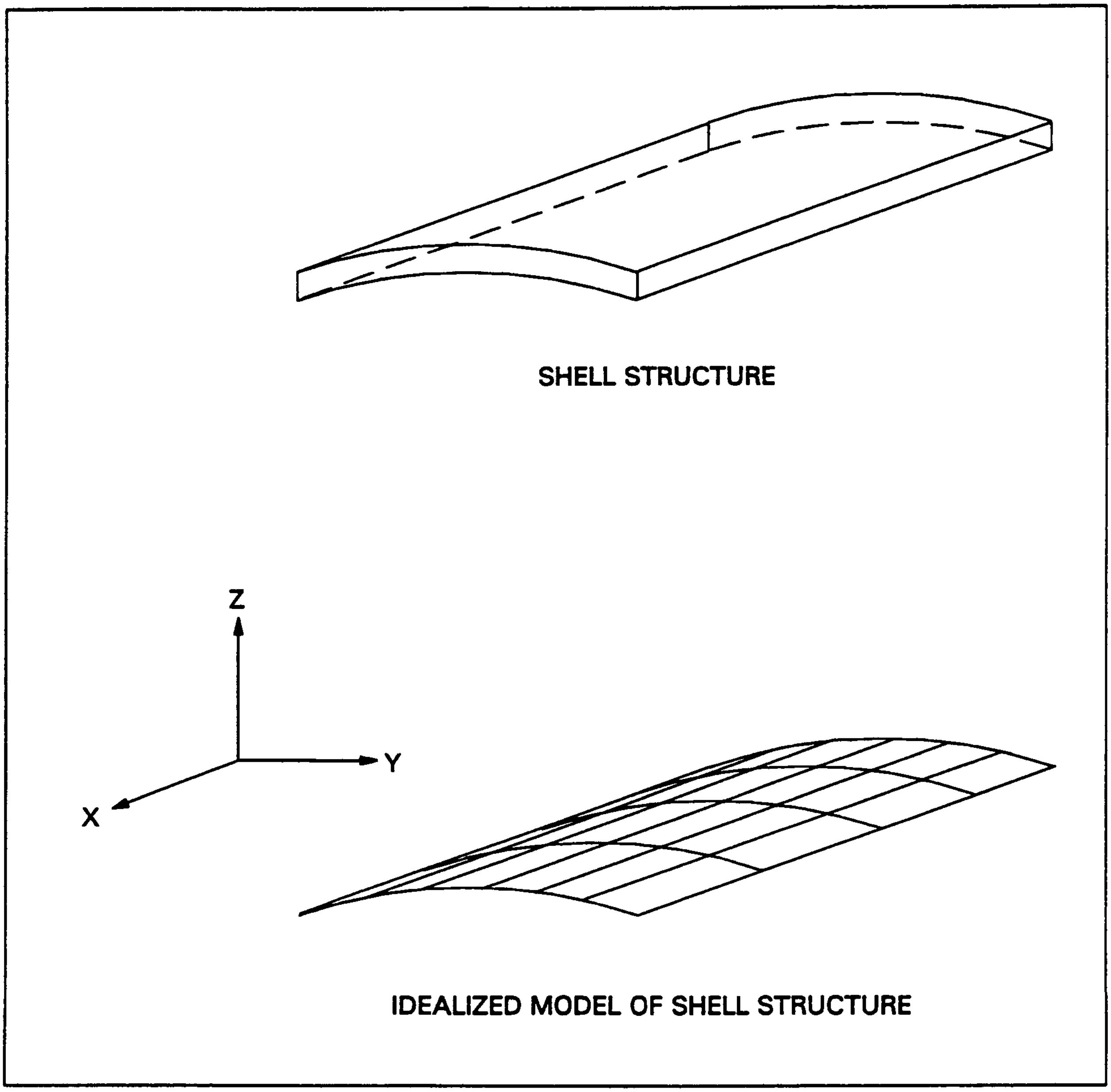

Figure 3.4: A Shell Structure Modeled Using The SPLATE Option in HITCAN

Note that (y,z) coordinates in each cross section can be input in 2 different ways, as follows:

(1) For each y point, two values of the z-coordinate, for the upper and the lower surface, must be input (see Figure 3.5). The thickness and the mid-surface of the structure are automatically calculated by the code. This option is activated by entering a value of 1 or 2 for the variable IGRD. The geometry modeling data are input through variables X, Y, ZU, and ZL for each cross section.

(2) For each y point, one value of the z-coordinate, for the mid-plane of the structure and the structure thickness must be input (see figure 3.5). The upper and the lower surfaces of the structure are automatically calculated by the code. This option is activated by inputting a value of 3 or 4 for the variable IGRD. The geometry modeling data are input through the variables X, Y, Z, and TB for each cross section.

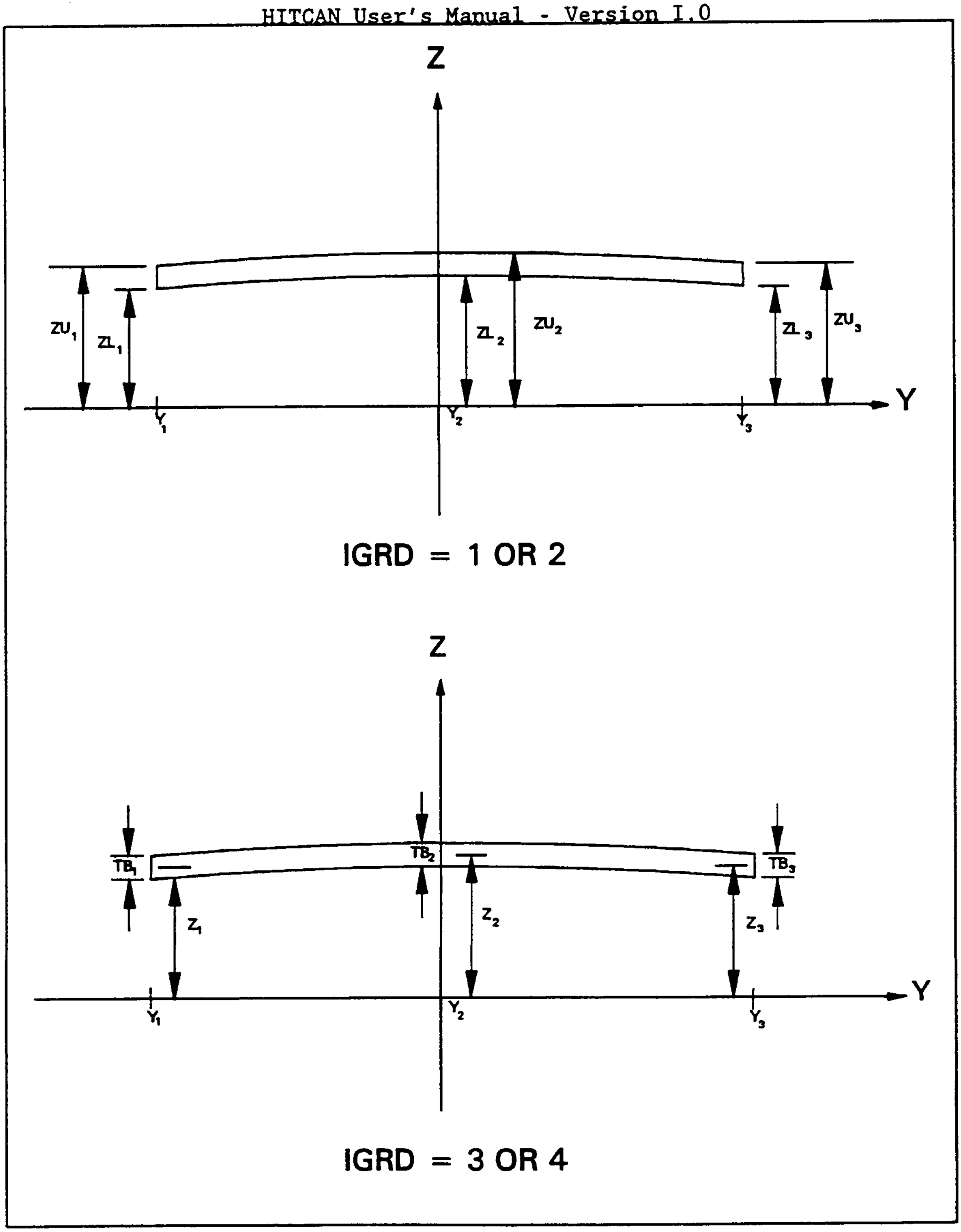

Figure 3.5: Input Options For The SPLATE Model Cption

Note that by setting IGRD equal to 1 or 4, HITCAN will divide the model into IU-1 elements along the x-axis and JU-1 elements along the y-axis using a cubic spline interpolating function. With IGRD having a value of 2 or 3, the input points are assumed to be the nodes and the variables X, Y, ZL, ZU, Z, and TB are nodal quantities. HITCAN will automatically generate the element connectivities. These variables are illustrated in the Figure 3.6 on the following page.

Program Option card: SPLATE MODEL

Card Groups: 5 and 27

Columns	Format	Variable Name	Entry
1st card in card group 5			
1-4	I4	NSECT	The number of input cross sections. A sufficient number must be used so that the surface geometry can be properly represented by a cubic spline. Note, if the surface is linear only two points are needed. The coordinates of the points are entered below, using X, Y, Z, ZL, ZU, and TB.
2nd card in card group 5			
1-4	I4	IGRD	Sets the input format. If IGRD is set to 1 or 4, a finite element mesh will be generated. Setting IGRD equal to 2 or 3 the input points will be assumed to be nodes of a finite element mesh, the element connectivity will then be automatically created.
5-8	I4	IU	For IGRD equal to 1 or 4, the number of nodes in the finite element model along the x-axis. With IGRD set to 2 or 3, IU is the number of nodes that are input along the x-axis; i. e., IU is equal to NSECT.
9-12	I4	JU	For IGRD equal to 1 or 4, the number of nodes in the finite element model along the y-axis. With IGRD set to 2 or 3, JU is the number of nodes that are input along the y-axis; i. e., JU is equal to MSECT.

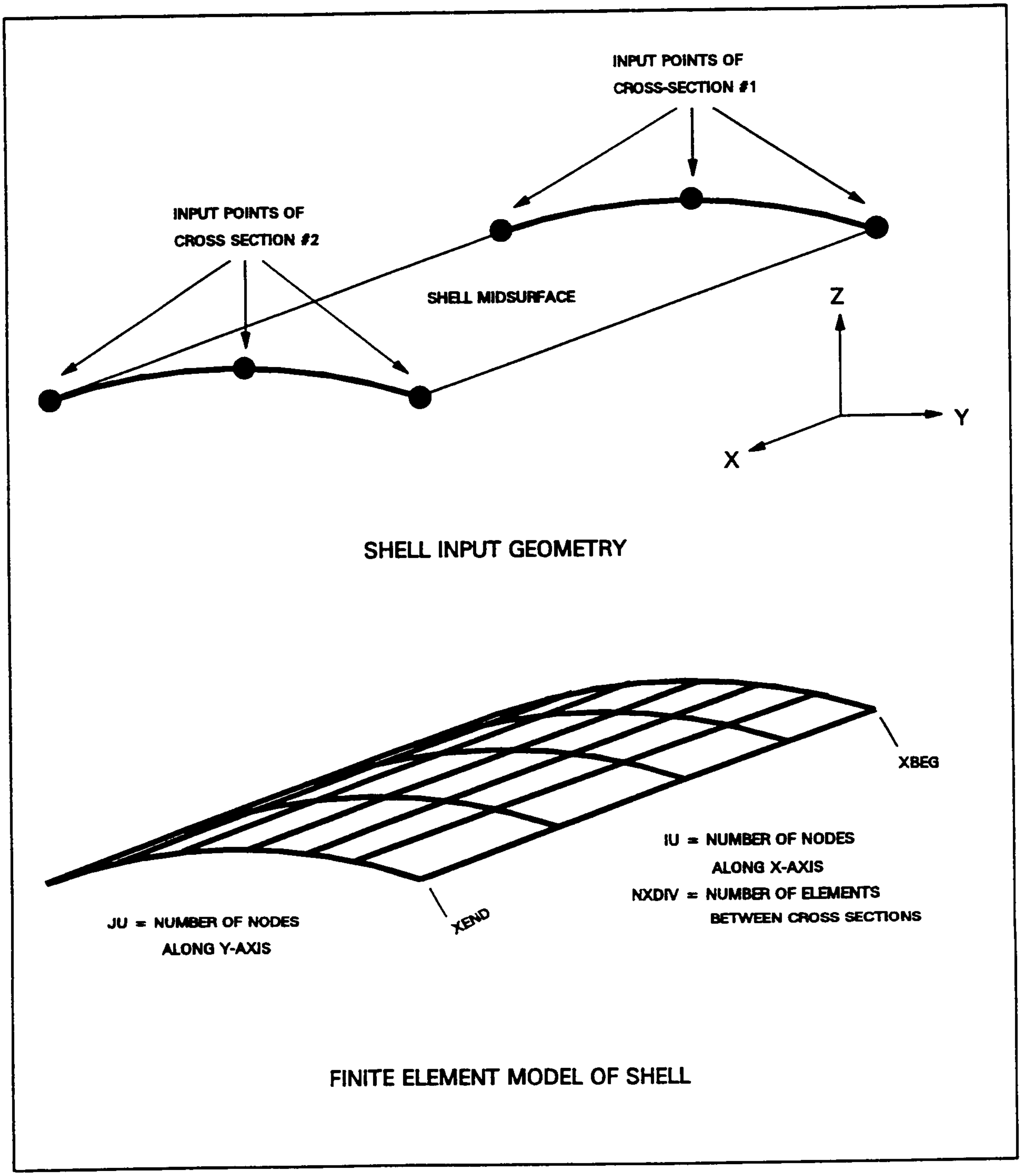

Figure 3.6: Variables Used In The SPLATE Model Option

Columns	Format	Variable Name	Entry
3rd card in card group 5			
1-8	F8.4	XBEG	The initial x coord. of structure, use if IGRD = 1 or 4
9-16	F8.4	XEND	The final x coord. of structure, use if IGRD = 1 or 4
1st card in card group 27			
1-80	20I4	MSECT	Number of input points at each cross section. If IGRD is equal to 2 or 3, then the number of input points must be the same for each cross section.
2nd card in card group 27			
1-4	I4	NXDIV	Number of elements between two consecutive output sections
3rd card in card group 27			
1-8	F8.4	X	X coordinate of an input point
9-16	F8.4	Y	Y coordinate of an input point
17-24	F8.4	Z or ZU	If IGRD = 1 or 2, use ZU. ZU is the Z coordinate of the upper surface. If IGRD = 3 or 4, use Z. Z is the Z coordinate of the mid-plane.
25-32	F8.4	TB or ZL	If IGRD = 1 or 2, use ZL. ZL is the Z coordinate of the lower surface. If IGRD = 3 or 4, use TB. Tb is the wall thickness.

One block of data for each input cross section. Each block will contain MSECT(J) cards of card #3 and 1 card of card #2. The coordinates of each input point will be on one card. The total number of cards will be MSECT(1) + MSECT(2) +...+ MSECT(I) + NSECT, where I=1,NSECT.

EXAMPLE:

In this example, the input required for a plate of length 4 in., of width 2 in., and a thickness of 0.1 in. is given. In the finite element mesh there will be 4 elements along the x-axis and 4 elements along the y-axis.

Card Group 5

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   2
   4   4   4
     0.0       4.0
```

Card Group 27

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   2    2
   3
       0.0        -1.0       0.0       0.1
       0.0         1.0       0.0       0.1

  0
       4.0        -1.0       0.0       0.1
       4.0         1.0       0.0       0.1
```

Columns	Field Name	Value	Description
1-4	NSECT	1	There is 2 input sections.
1-4	IGRD	4	Since IGRD equals = 4, a finite element model will be created.
5-8	IU	4	Number of nodes along the x-axis.
9-12	JU	4	Number of nodes along the y-axis.
1-8	XBEG	0.0	The initial x coordinate of the plate.
9-16	XEND	4.0	The final x coordinate of the plate.
1-4	NXDIV	3	Number of elements between the 1st and 2nd output sections.
1-10	X	0.0	X coordinate of input point #1 of input section #1.
11-20	Y	-1.0	Y coordinate of input point #1 of input section #1.
21-30	Z	0.0	Z coordinate of input point #1 of input section #1.
31-40	TB	0.1	The thickness of input point #1 of input section #1.
1-10	X	0.0	X coordinate of input point #2 of input section #1.
11-20	Y	1.0	Y coordinate of input point #2 of input section #1.

Columns	Field Name	Value	Description
21-30	Z	0.0	Z coordinate of input point #2 of input section #1.
31-40	TB	0.1	The thickness of input point #2 of input section #1.
1-4	NXDIV	0	
1-10	X	4.0	X coordinate of input point #1 of input section #2.
11-20	Y	-1.0	Y coordinate of input point #1 of input section #2.
21-30	Z	0.0	Z coordinate of input point #1 of input section #2.
31-40	TB	0.1	The thickness of input point #1 of input section #2.
1-10	X	4.0	X coordinate of input point #2 of input section #2.
11-20	Y	1.0	Y coordinate of input point #2 of input section #2.
21-30	Z	0.0	Z coordinate of input point #2 of input section #2.
31-40	TB	0.1	The thickness of input point #2 of input section #2.

HPLATE MODEL OPTION

The HPLATE model option allows modeling of hollow sandwich type structures with different shaped top and bottom plates, joined by multiple different sized plate type spars. Figure 3.7 shows an example of this type of structure. The top and bottom plates can have arbitrary shapes in x and y directions. The spars are defined as plates with faces in the x,z plane and thickness in the y-direction, joining the top and bottom plates, at user-specified points. Note if the spars in the structure are evenly spaced, then the program option card PANEL must also be specified.

HITCAN assumes the nodal input points are on the outer surface of the shell. HITCAN automatically corrects the grid point positions by moving them to the mid-wall position in a direction normal to the surface. The program option card will suppress this mid-wall correction and will retain the grid points on the external profile of the shell.

The finite element mesh is generated in the following steps.

Step 1: A right-handed rectilinear coordinate system (x,y,z) is defined, placing the center of the coordinate system at a convenient point.

Step 2: The basic shape of the top and bottom plates is divided into cross sections ((y,z) planes), definable with cubic splines. The number of cross sections selected along the x-axis depends upon the curvature of the structure along the x-axis. The curvature along the x-axis can be different for the top and bottom plates of the sandwich structure. This must be kept in mind when selecting the number of cross sections.

Step 3: Each cross section ((y,z) plane) consist of input points. The number of (y,z) input points needed to define a specific cross section are again selected so that the curve between the two adjacent points can be modeled using a cubic spline interpolator. A different number of (y,z) input points can be selected for different cross sections and for the top and bottom surfaces.

Step 4: The desired nodal point coordinates are automatically interpolated, by defining the number of elements desired between each output section and the number of elements desired along the y-axis. The spars are divided into same number of elements along the x-axis as the top and the bottom plates. The spars can only consist of one element in the y and z directions.

Figure 3.8 illustrates several of the variables used in the HPLATE model option.
Program Option card:

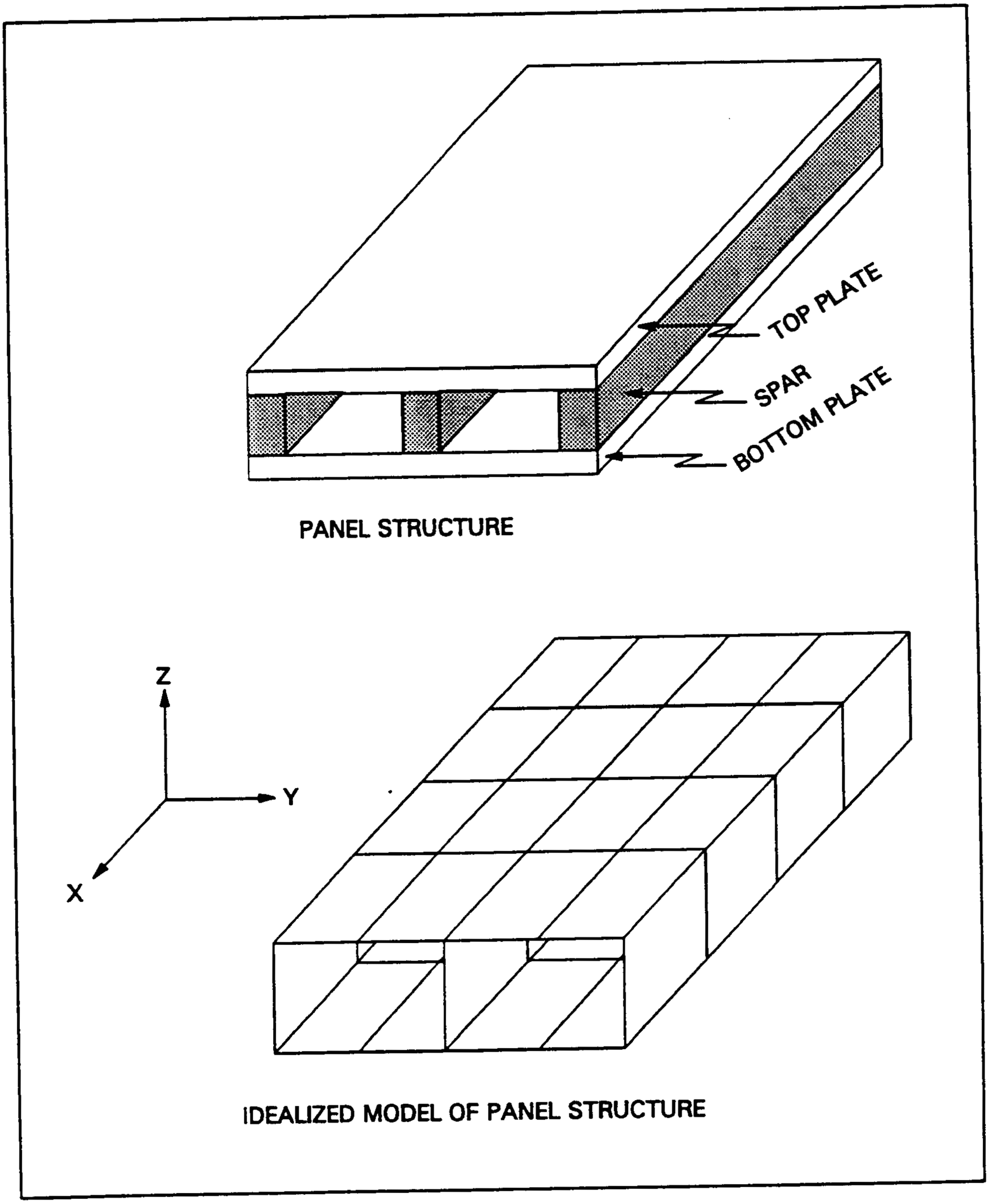

Figure 3.7: A Panel Structure Modeled Using The HPLATE Option in HITCAN

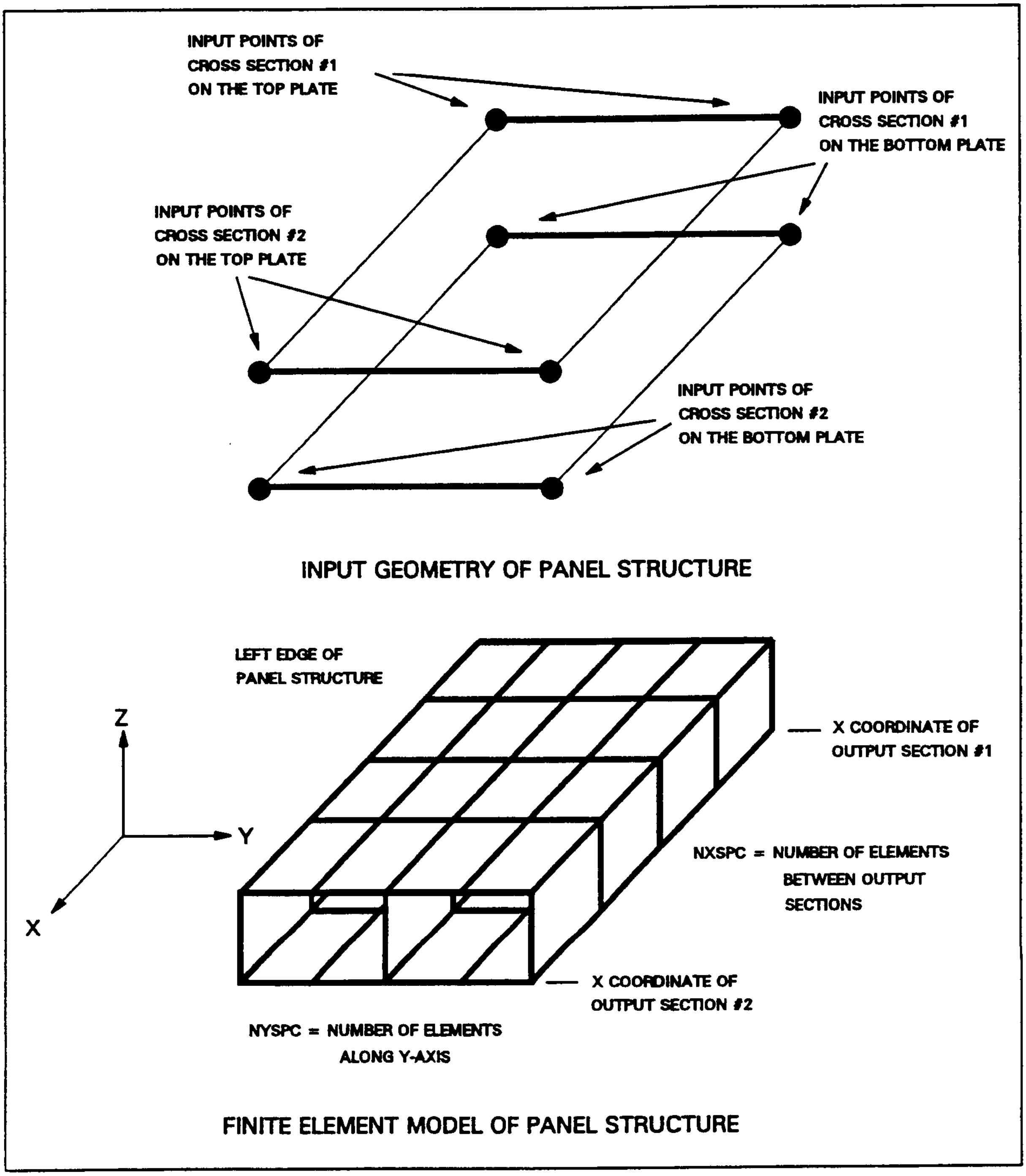

Figure 3.8: Variables Used In The HPLATE Model Option

Program Option Cards: HPLATE MODEL OPTION
PROFILE
PANEL

Card Groups: 2, 9, and 24

Columns	Format	Variable Name	Entry
1st card in card group 2			
1-4	I4	NSECT	Number of output sections.
5-8	I4	NXSPAR	Number of output sections containing spars
9-12	I4	NSPAR	Number of spars in an output section. Note that each output section must have the same number of spars.
13-16	I4	NYSPC	Number of elements desired along the y-axis. The top and bottom plates will have the same number of elements. If PANEL is specified the number of elements will be SPC+1.
1st card in card group 9			
1-80	20I4	LSECT(1)	Number of input cross sections for the top surface. A sufficient number must be used so that the surface geometry can be properly represented by a cubic spline.
1-80	20I4	LSECT(1)	Number of input cross sections.
1st card of card group 24			
1-80	20I4	NSPDES	Spar ply designation numbers.
2nd card of card group 24			
1-4	I4	NXSPC	Number of elements in the FE model between output sections
5-10	F6.2	XH	X coordinate of an output section

3rd card in card group 24

1-10	F10.4	SY(1)	Y coordinate of spar as measured from the left edge of the structure
11-20	F10.4	SY(2)	Wall thickness of spar
21-30	F10.4	SY(1)	Y coordinate of spar as measured from the left edge of the structure
31-40	F10.4	SY(2)	Wall thickness of spar
41-50	F10.4	SY(1)	Y coordinate of spar as measured from the left edge of the structure
51-60	F10.4	SY(2)	Wall thickness of spar
61-70	F10.4	SY(1)	Y coordinate of spar as measured from the left edge of the structure
71-80	F10.4	SY(2)	Wall thickness of spar

Cards 2 and 3 are repeated NSECT+1 times

4th card of card group 24

1-80	20I4	MSECT	An array containing the number of input points for each input cross section. This is for the top surface.

5th card of card group 24

1-80	20I4	MSECT	An array containing the number of input points for each input cross section. This is for the top surface.

6th card in card group 24

1-8	F8.4	X	X coordinate of an input point on the top surface
9-16	F8.4	Y	Y coordinate of an input point on the top surface
16-24	F8.4	Z	Z coordinate of an input point on the top surface
25-32	F8.4	THK	Wall thickness of an input point on the top surface

This card is repeated MSECT(1,1) + MSECT(2,1), +...+ MSECT(I,1), where I = 1,LSECT(1).

7th card in card group 24

1-8	F8.4	X	X coordinate of an input point on the top surface
9-16	F8.4	Y	Y coordinate of an input point on the top surface
16-24	F8.4	Z	Z coordinate of an input point on the top surface
25-32	F8.4	THK	Wall thickness of an input point on the top surface

This card is repeated MSECT(1,2) + MSECT(2,2), +...+ MSECT(I,2), where I = 1,LSECT(2).

EXAMPLE:

In this example, the input is given for a panel. The length of the panel is 0.5 in., the width is 0.2 in., and the height of the panel is 0.075 in. The panel has 2 spars one on each end. Each spar has a thickness of 0.02 in.

Card Group 2

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   2   2   2   7
```

Card Group 9

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   2   2
```

Card Group 24

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1   1
   4    .0
        .0       .02        .2       .02
        .5
        .0       .02        .2       .02
   2   2
   2   2
        .0       -.1       .04       .02
        .0        .1       .04       .02
        .5       -.1       .04       .02
        .5        .1       .04       .02
        .0       -.1      .035       .01
        .0        .1      .035       .01
        .5       -.1      .035       .01
        .5        .1      .035       .01
```

Columns	Field Name	Value	Description
1-4	NSECT	1	Number of output sections is 1.
5-8	NXSPAR	2	Both output sections are to contain spars.
9-12	NSPAR	2	Number of spars is 2.
13-16	NYSPC	7	Number of elements along the Y-axis
1-4	LSECT(1)	2	The top surface is described by 2 input sections.
5-8	LSECT(2)	2	The bottom surface is described by 2 input sections.
1-4	NSPDES(1)	1	Spar #1 is described by ply designation #1.

Columns	Field Name	Value	Description
5-8	NSPDES(2)	1	Spar #2 is described by ply designation #2.
1-4	NXSPC	4	Number of elements along the x-axis between output sections #1 and #2.
5-10	XH	0.0	The x coordinate of the 1st output section.
1-10	SY(1)	0.0	Y coordinate of spar #1.
11-20	SY(2)	0.02	Wall thickness of spar #1.
21-30	SY(1)	0.2	Y coordinate of spar #2.
31-40	SY(2)	0.02	Wall thickness of spar #2.
1-4	NXSPC	0	
5-10	XH	0.0	The x coordinate of the 2nd output section.
1-10	SY(1)	0.0	Y coordinate of spar #1.
11-20	SY(2)	0.02	Wall thickness of spar #1.
21-30	SY(1)	0.2	Y coordinate of spar #2.
31-40	SY(2)	0.02	Wall thickness of spar #2.
1-4	MSECT(1)	2	Two inputs described the 1st input section on the top surface.
5-8	MSECT(2)	2	Two inputs described the 1st input section on the top surface.
1-4	MSECT(1)	2	Two inputs described the 1st input section on the bottom surface.
5-8	MSECT(2)	2	Two inputs described the 1st input section on the bottom surface.
1-10	X	0.0	X coordinate of input point #1 at input section #1 on the top surface.
11-20	Y	-.1	Y coordinate of input point #1 at input section #1 on the top surface.
21-30	Z	0.04	Z coordinate of input point #1 at input section #1 on the top surface.
31-40	THK	0.02	Wall thickness of input point #1 at input section #1 on the top surface.
1-10	X	0.5	X coordinate of input point #2 at input section #1 on the top surface.
11-20	Y	0.1	Y coordinate of input point #2 at input section #1 on the top surface.
21-30	Z	0.04	Z coordinate of input point #2 at input section #1 on the top surface.
31-40	THK	0.02	Wall thickness of input point #1 at input section #2 on the top surface.
1-10	X	0.5	X coordinate of input point #1 at input section #2 on the top surface.
11-20	Y	-.1	Y coordinate of input point #1 at input section #2 on the top surface.
21-30	Z	0.04	Z coordinate of input point #1 at input section #2 on the top surface.
31-40	THK	0.02	Wall thickness of input point #1 at input section #2 on the top surface.

Columns	Field Name	Value	Description
1-10	X	0.0	X coordinate of input point #2 at input section #2 on the top surface.
11-20	Y	0.1	Y coordinate of input point #2 at input section #2 on the top surface.
21-30	Z	0.04	Z coordinate of input point #2 at input section #2 on the top surface.
31-40	THK	0.02	Wall thickness of input point #2 at input section #2 on the top surface.
1-10	X	0.0	x coordinate of input point #1 at input section #1 on the bottom surface.
11-20	Y	-.1	Y coordinate of input point #1 at input section #1 on the bottom surface.
21-30	Z	0.035	Z coordinate of input point #1 at input section #1 on the bottom surface.
31-40	THK	0.02	Wall thickness of input point #1 at input section #1 on the bottom surface.
1-10	X	0.0	X coordinate of input point #2 at input section #1 on the bottom surface.
11-20	Y	0.1	Y coordinate of input point #2 at input section #1 on the bottom surface.
21-30	Z	0.035	Z coordinate of input point #2 at input section #1 on the bottom surface.
31-40	THK	0.01	Wall thickness of input point #1 at input section #2 on the bottom surface.
1-10	X	0.5	X coordinate of inpt point #1 at input section #2 on the bottom surface.
11-20	Y	-.1	Y coordinate of input point #1 at input section #2 on the bottom surface.
21-30	Z	0.035	Z coordinate of input point #1 at input section #2 on the bottom surface.
31-40	THK	0.01	Wall thickness of input point #1 at input secttion #2 on the bottom surface.
1-10	X	0.5	X coordinate of input point #2 at input section #2 on the bottom surface.
11-20	Y	0.1	Y coordinate of input point #2 at input section #2 on the bottom surface.
21-30	Z	0.035	Z coordinate of input point #2 at input section #2 on the bottom surface.
31-40	THK	0.01	Wall thickness of input point #2 at input section #2 on the bottom surface.

S3DSOLID MODEL OPTION

This model option enables the user to create a finite element model of a solid structure using 3D solid elements. Figure 3.9 shows an example of the type of structure that can be modeled using this model option. The finite element mesh is generated in the following steps.

Step 1: A right-handed rectilinear coordinate system (x,y,z) is defined, placing the center of the coordinate system at a convenient point on the structure.

Step 2: The basic shape of the structure is divided into input planes. As shown in the Figure 3.10, a quarter of a ring that was broken into two input planes. One input plane represents the inside surface of the ring, the other the outside surface of the ring. The number of input planes used will depend upon the curvature of the structure along the z-axis. A sufficient number must be provided so that a cubic spline can be used.

Step 3: Each input plane is separately divided into several sets of input points. The number of sets used must be sufficient so that the curvature in the input plane can be represented by a cubic spline. The number of sets of points for each input plane can be different; likewise, the number of points in each set can be different.

Step 4: The desired nodal point coordinates are automatically interpolated, by defining the number of elements desired between each output section, the number of elements along the y-axis, and the number of elements along the z-axis.

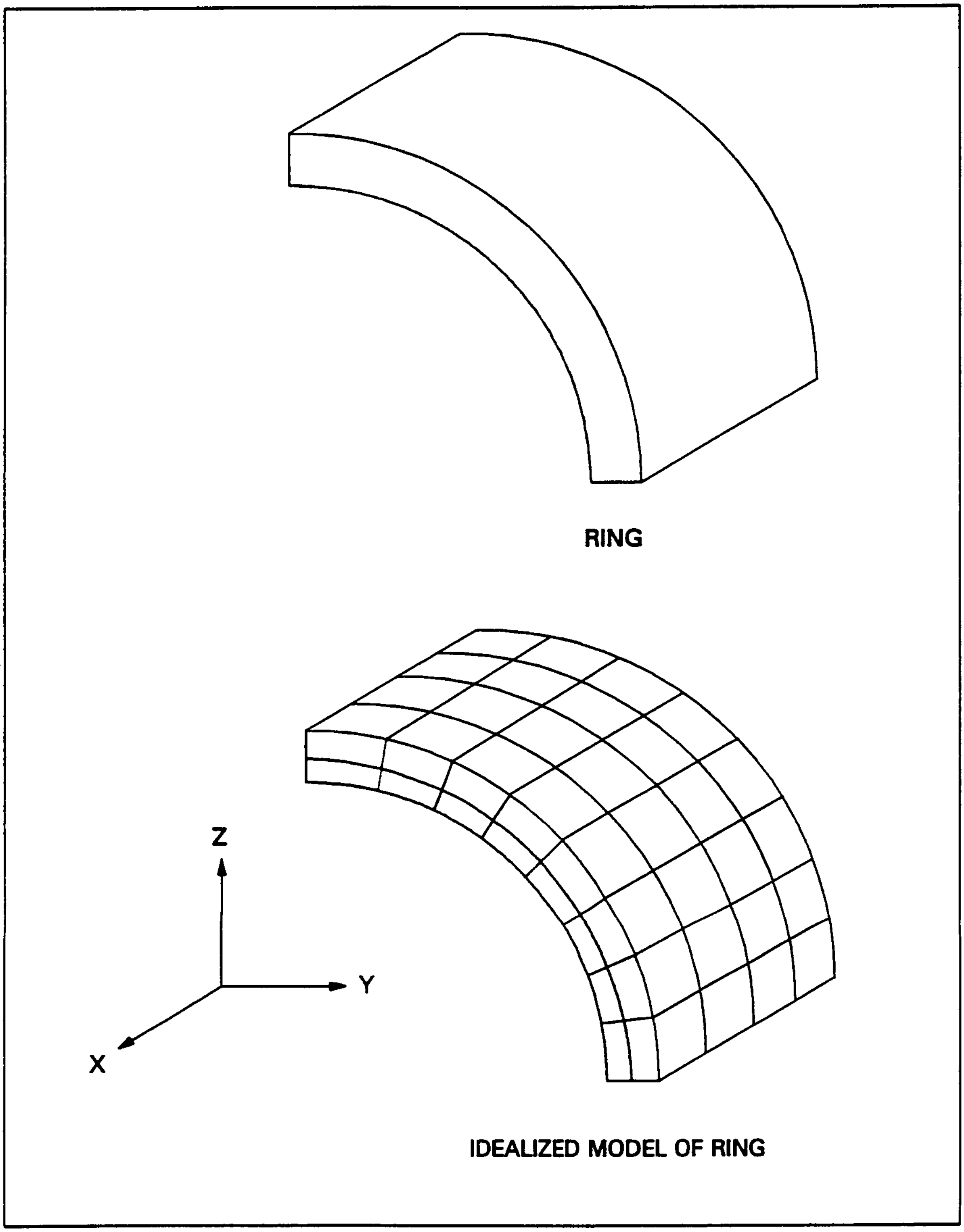

Figure 3.9: A Ring Modeled Using The S3DSOLID Option In HITCAN

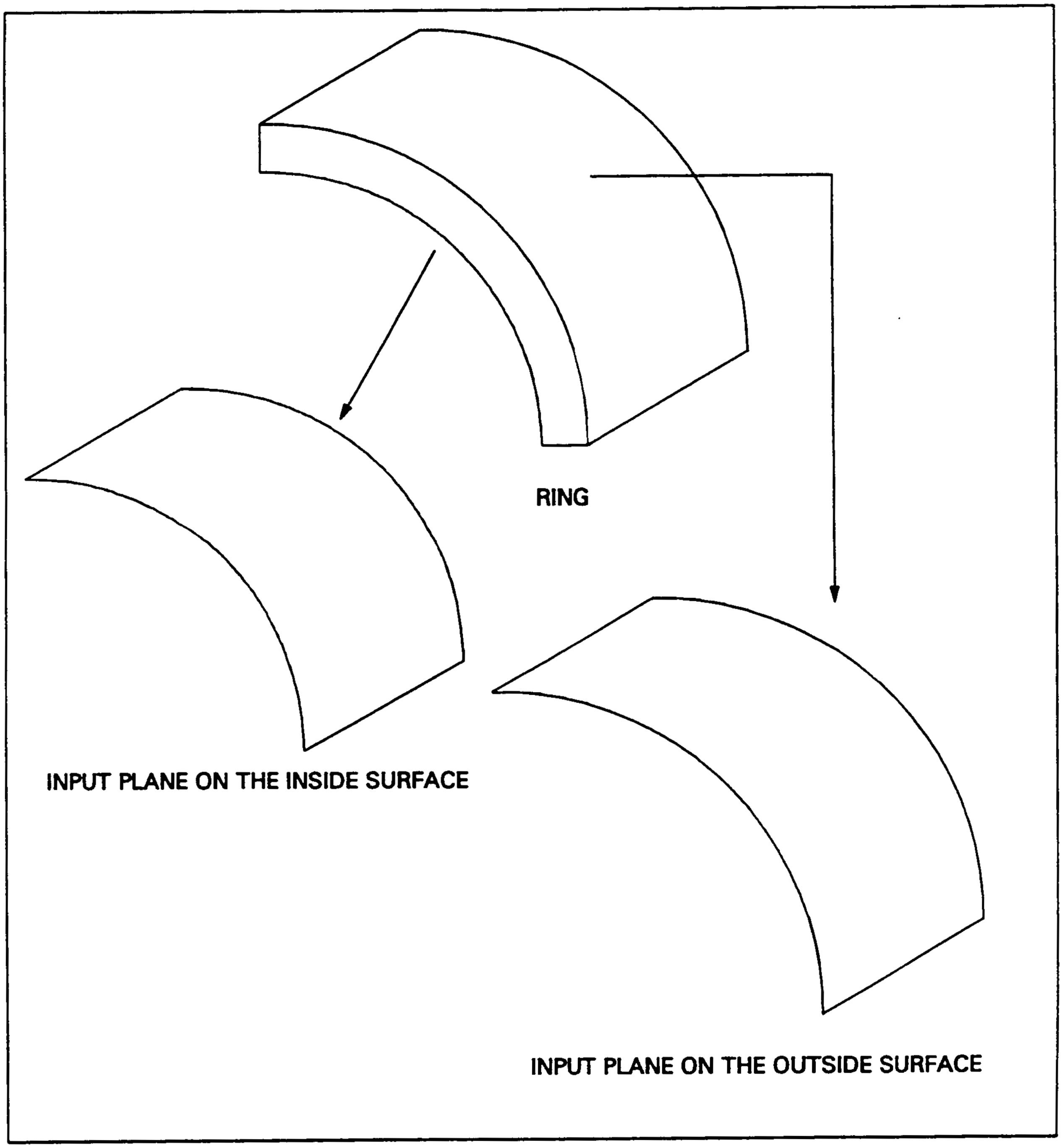

Figure 3.10: Input Planes For One Quarter Of A Ring

Program Option card: S3DSOLID MODEL OPTION

Card Groups: 4, and 26

Columns	Format	Variable Name	Entry
1st card of card group 4			
1-4	I4	NIPL	Number of input planes. A sufficient number must be used so that the curvature can be properly represented by a cubic spline.
5-8	I4	NOSC	Number of output sections.
9-12	I4	NEYY	Number of elements along the y-axis in the finite element model.
13-16	I4	NETT	Number of elements along the z-axis in the finite element model.
1st card of card group 26			
1-4	I4	NXSPC	Number of elements between output sections along the x-axis.
5-10	F6.2	X	X coordinate of an output section. The above card is repeated NOSC+1 times.
2nd card of card group 26			
1-80	20I4	LSECT	An array containing the number of sets of points in an input plane. A sufficient number must be used so that the curvature lying in the input plane can be properly represented.
3rd card of card group 26			
1-80	20I4	MSECT	An array containing the number of input points for each set of input points.

Card #3 is repeated NIPL times.

4th card of card group 26

Columns	Format	Variable Name	Entry
1-8	F8.4	X	X coordinate of an input point.
9-16	F8.4	Y	Y coordinate of an input point.
17-24	F8.4	Z	Z coordinate of an input point.

This card is repeated as follows. One block of data for each input plane, i. e.,

NIPL blocks of data. Each block will contain LSECT sets of points, with each set containing MSECT input points. Thus for input plane #2, card #4 is repeated MSECT(1) + MSECT(2) +...+ MSECT(I) times, where I = 1,LSECT(2).

EXAMPLE:

The input for a sector of a ring is shown in this example. The inside radius of the ring is 2.875 in. and the outside radius of the ring is 3.475.

Card Group 4

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   2   3   3   6
```

Card Group 26

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   2    .0
        .6
   2   2
   2   2
   2   2
      .0        .0      2.875
      .0        .1      2.873
      .6        .0      2.875
      .6        .1      2.873
      .0        .0      3.475
      .0      .121      3.473
      .6        .0      3.475
      .6      .121      3.473
```

Columns	Field Name	Value	Description
1-4	NIPL	2	Number of input planes.
5-8	NOSC	3	Number of output sections.
9-12	NEYY	3	Number of elements along the Y-axis.
13-16	NETT	6	Number of elements through the thickness.
1-4	NXSPC	2	Number of elements between output sections #1 and #2.
5-10	X	0.0	X coordinate of the 1st output section.
1-4	NXSPC	0	
5-10	X	0.6	X coordinate of the 2nd output section.
1-4	LSECT(1)	2	Number of input sections on input plane #1.
5-8	LSECT(2)	2	Number of input sections on input plane #2.
1-4	MSECT(1)	2	Number of input points in the 1st set of input points of input plane #1.
5-8	MSECT(2)	2	Number of input points in the 2nd set of input points of input plane #1.

Columns	Field Name	Value	Description
1-4	MSECT(1)	2	Number of input points in the 1st set of input points of input plane #2.
5-8	MSECT(2)	2	Number of input points in the 2nd set of input points of input plane #2.
1-8	X	0.0	X coordinate of point #1 in the 1st set of input points on plane #1.
9-16	Y	0.0	Y coordinate of point #1 in the 1st set of input points on plane #1.
17-24	Z	2.875	Z coordinate of point #1 in the 1st set of input points on plane #1.
1-8	X	0.0	X coordinate of point #2 in the 1st set of input points on plane #1.
9-16	Y	0.1	Y coordinate of point #2 in the 1st set of input points on plane #1.
17-24	Z	2.873	Z coordinate of point #2 in the 1st set of input points on plane #1.
1-8	X	0.6	X coordinate of point #1 in the 2nd set of input points on plane #1.
9-16	Y	0.0	Y coordinate of point #1 in the 2nd set of input points on plane #1.
17-24	Z	2.875	Z coordinate of point #1 in the 2nd set of input points on plane #1.
1-8	X	0.6	X coordinate of point #2 in the 2nd set of input points on plane #1.
9-16	Y	0.1	Y coordinate of point #2 in the 2nd set of input points on plane #1.
17-24	Z	2.873	Z coordinate of point #2 in the 2nd set of input points on plane #1.
1-8	X	0.0	X coordinate of point #1 in the 1st set of input points on plane #2.
9-16	Y	0.0	Y coordinate of point #1 in the 1st set of input points on plane #2.
17-24	Z	3.475	Z coordinate of point #1 in the 1st set of input points on plane #2.
1-8	X	0.0	X coordinate of point #2 in the 1st set of input points on plane #2.
9-16	Y	0.121	Y coordinate of point #2 in the 1st set of input points on plane #2.
17-24	Z	3.473	Z coordinate of point #2 in the 1st set of input points on plane #2.
1-8	X	0.6	X coordinate of point #1 in the 2nd set of input points on plane #2.
9-16	Y	0.0	Y coordinate of point #1 in the 2nd set of input points on plane #2.
17-24	Z	3.475	Z coordinate of point #1 in the 2nd set of input points on plane #2.

Columns	Field Name	Value	Description
1-8	X	0.6	X coordinate of point #2 in the 2nd set of input points on plane #2.
9-16	Y	0.121	Y coordinate of point #2 in the 2nd set of input points on plane #2.
17-24	Z	3.473	Z coordinate of point #2 in the 2nd set of input points on plane #2.

READ IN MODEL

This option allows the user to input a finite element model using eight-node solid elements. The user must provide the element connectivities and the nodal coordinates. When this option is chosen, the user must also specify the BRICK program option card.

Program option cards: READ IN MODEL and BRICK

Card groups: 3 and 25

Columns	Format	Variable Name	Entry
1st card in card group #3			
1-4	I4	MAXNP	Number of nodes in the finite element model.
5-8	I4	NETOT	Number of elements in the finite element model.
1st card in card group #25			
1-4	I4	IELE	Element number.
5-36	8I4	KEI	Element connectivity. See description of the solid element for the correct order of the nodes in the element connectivity.

Card #1 is repeated NETOT times.

2nd card in card group #25

Columns	Format	Variable Name	Entry
1-5	I5	NNUM	Node number.
6-10	5X		
11-20	F10.4	X	X coordinate.
21-30	F10.4	Y	Y coordinate.
31-40	F10.4	Z	Z coordinate.

Card #2 is repeated MAXNP times

EXAMPLE:

Card Group 3

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   8   1
```

Card Group 25

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1   1   2   3   4   5   6   7   8
    1            1.0       1.0       0.0
    2            0.0       1.0       0.0
    3            0.0       1.0       1.0
    4            1.0       1.0       1.0
    5            1.0       0.0       0.0
    6            0.0       0.0       0.0
    7            0.0       0.0       1.0
    8            1.0       0.0       1.0
```

Columns	Field Name	Value	Description
1-4	MAXNP	8	Number of nodes is 8.
5-8	NETOT	1	Number of elements is 1.
1-4	IELE	1	Designation number of element #1.
5-8	KEI(1)	1	1st node in the element connectivity.
9-12	KEI(1)	2	2nd node in the element connectivity.
13-16	KEI(1)	3	3rd node in the element connectivity.
17-20	KEI(1)	4	4th node in the element connectivity.
21-24	KEI(1)	5	5th node in the element connectivity.
25-28	KEI(1)	6	6th node in the element connectivity.
29-32	KEI(1)	7	7th node in the element connectivity.
32-36	KEI(1)	8	8th node in the element connectivity.
1-5	NNUM	1	Node number for node #1.
11-20	X	1.0	X coordinate of node #1.
21-30	Y	1.0	Y coordinate of node #1.
31-40	Z	0.0	Y coordinate of node #1.
1-5	NNUM	2	Node number for node #2.
11-20	X	0.0	X coordinate of node #2.
21-30	Y	1.0	Y coordinate of node #2.
31-40	Z	0.0	Y coordinate of node #2.
1-5	NNUM	3	Node number for node #3.
11-20	X	0.0	X coordinate of node #3.
21-30	Y	1.0	Y coordinate of node #3.
31-40	Z	1.0	Y coordinate of node #3.
1-5	NNUM	4	Node number for node #4.

Columns	Field Name	Value	Description
11-20	X	1.0	X coordinate of node #4.
21-30	Y	1.0	Y coordinate of node #4.
31-40	Z	1.0	Y coordinate of node #4.
1-5	NNUM	5	Node number for node #5.
11-20	X	1.0	X coordinate of node #5.
21-30	Y	0.0	Y coordinate of node #5.
31-40	Z	0.0	Y coordinate of node #5.
1-5	NNUM	6	Node number for node #6.
11-20	X	0.0	X coordinate of node #6.
21-30	X	0.0	Y coordinate of node #6.
31-40	Z	0.0	Y coordinate of node #6.
1-5	NNUM	7	Node number for node #7.
11-20	X	0.0	X coordinate of node #7.
21-30	Y	0.0	Y coordinate of node #7.
31-40	Z	1.0	Y coordinate of node #7.
1-5	NNUM	8	Node number for node #8.
11-20	X	1.0	X coordinate of node #8.
21-30	Y	0.0	Y coordinate of node #8.
31-40	Z	1.0	Y coordinate of node #8.

3.2 ELEMENT TYPE

There are four types of elements available in HITCAN, a plane stress element, a plane strain element, a plate element, and eight-node solid element. These elements are activated by program option cards. The table below lists the available elements and their corresponding program option cards.

ELEMENT TYPE	PROGRAM OPTION CARD
Eight-Node Solid	BRICK
Four-Node Plate	PLATE
Plane Stress	STRAIN
Plane Strain	STRESS

BRICK

When this option is specified, a 8-node isoparametric 3D solid element will be used. This option card is to be used in conjunction with the S3DSOLID and the READ IN MODEL option cards. This element has 3 translational degrees of freedom identified by u_x, u_y, and u_z, as shown in Figure 3.11.

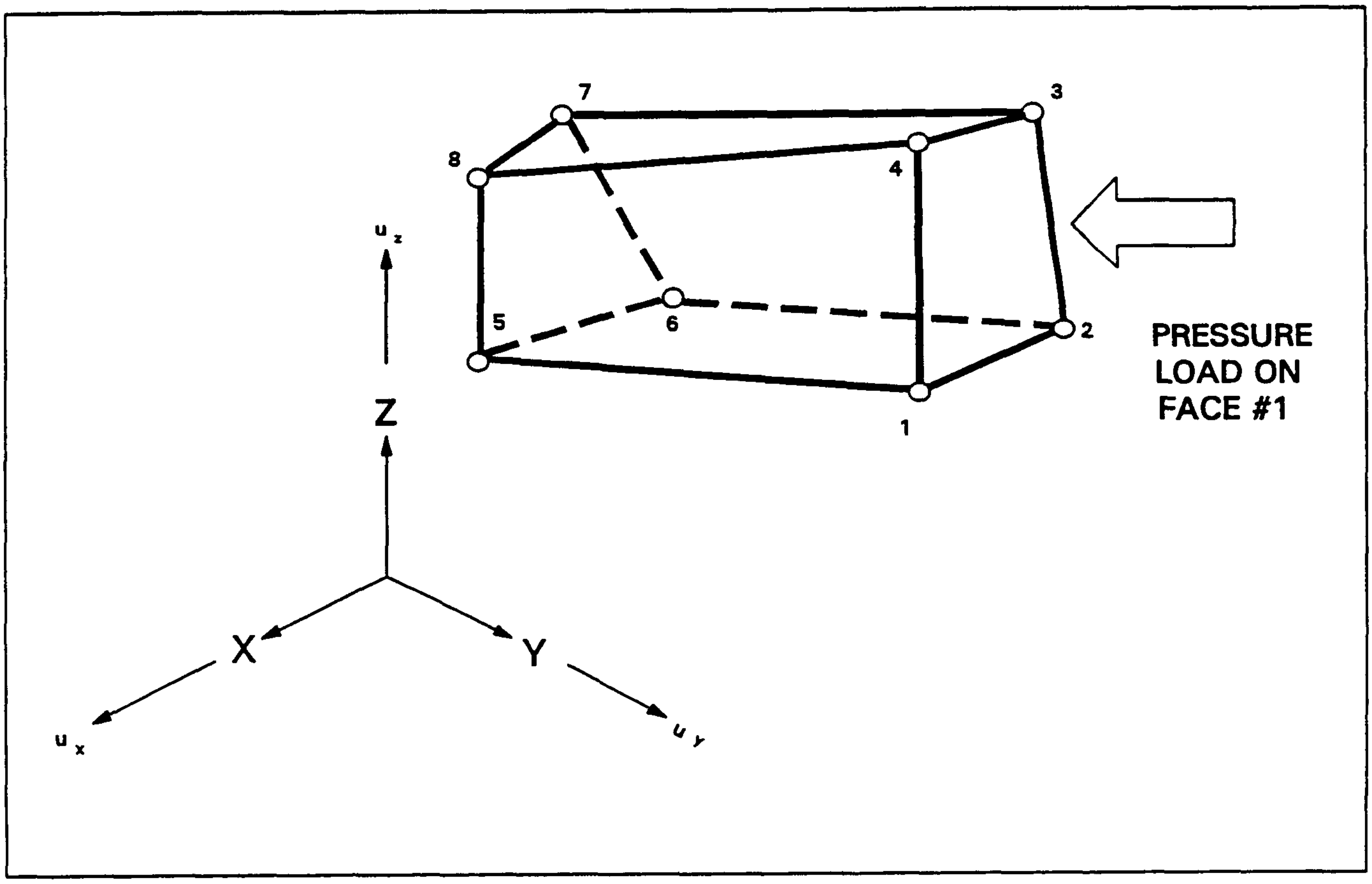

Figure 3.11: Eight-Node Solid Element

PLATE

This option selects the four-node isoparametic plate element both for the solid (SPLATE model option) and the hollow (HPLATE model option) structures. This element, which was derived from the Reissner-Mindlin theory for plates and shells, has 6 degrees-of-freedom at each node. These degrees-of-freedom are identified by u_x, u_y, u_z, H_x, H_y, and H_z. This element is shown in Figure 3.12.

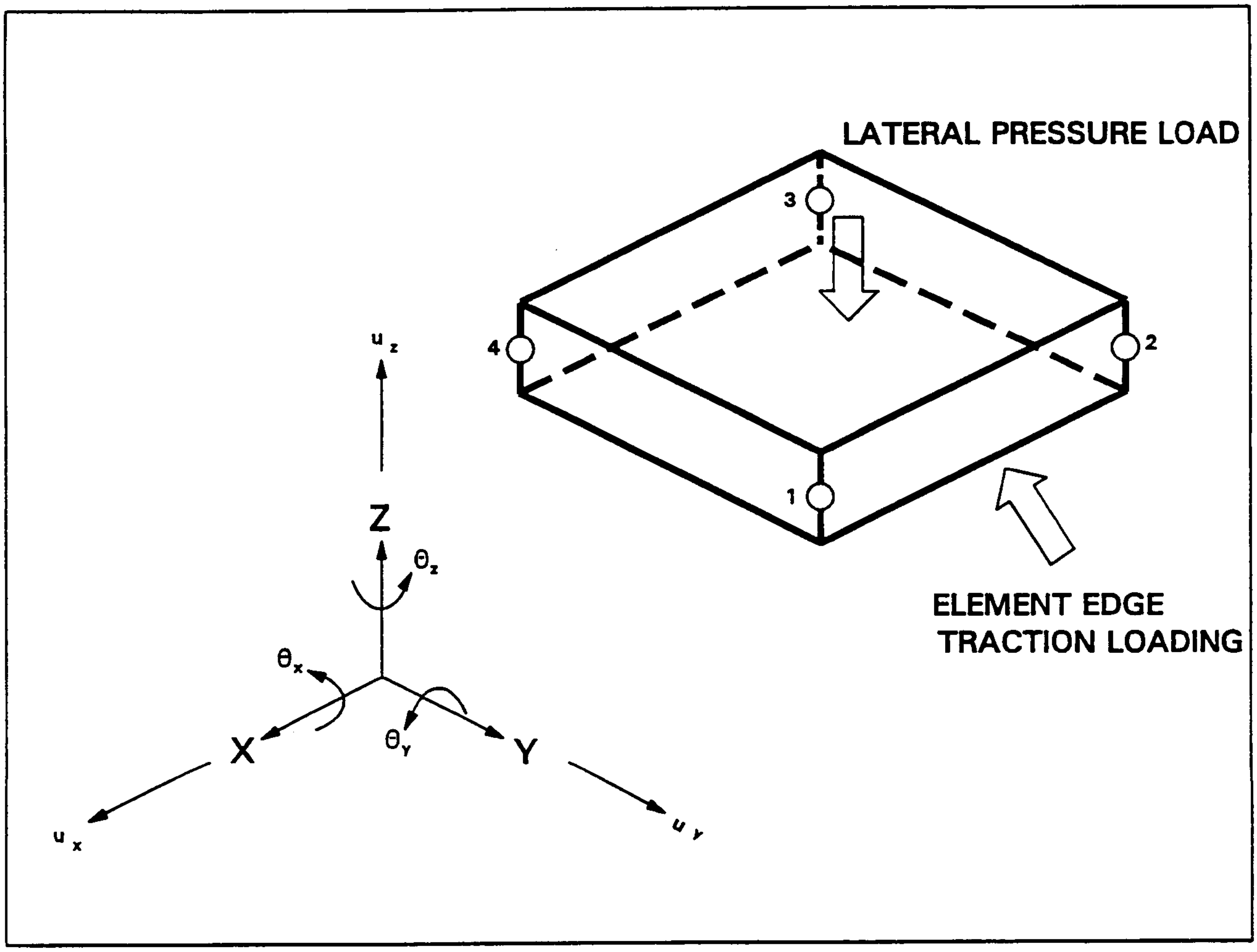

Figure 3.12: Plate Element

STRAIN

This option specifies, that a four-node isoparametic plane strain element will be used in the analysis. Each node within this element has 2 degrees-of-freedom, identified by u_x and u_y. This element is shown in Figure 3.13.

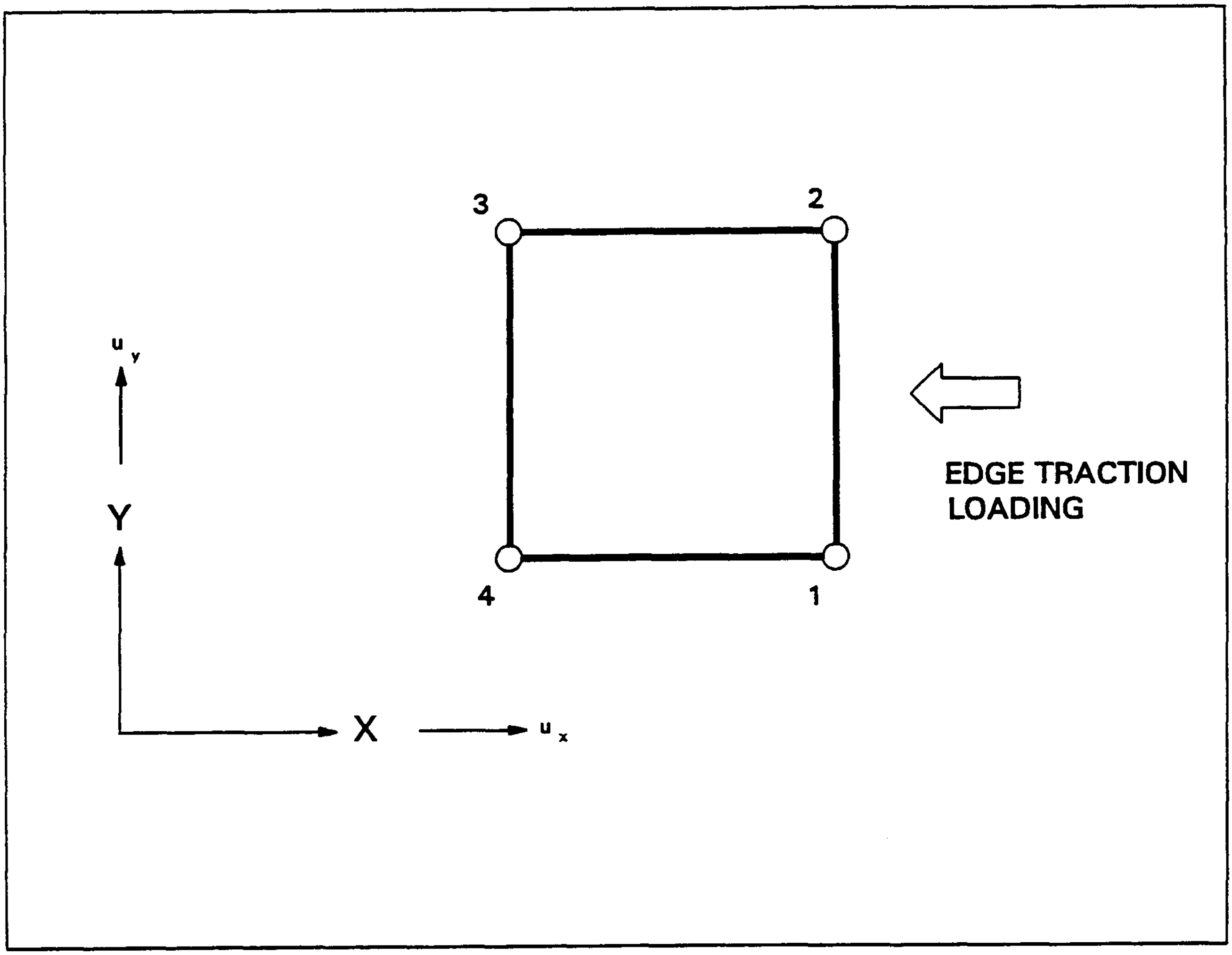

Figure 3.13: Plane Strain Element

STRESS

This option specifies, that a four-node isoparametic plane stress element will be used in the analysis. Each node within this element has 2 degrees-of-freedom, identified by u_x and u_y. This element is shown in Figure 3.14.

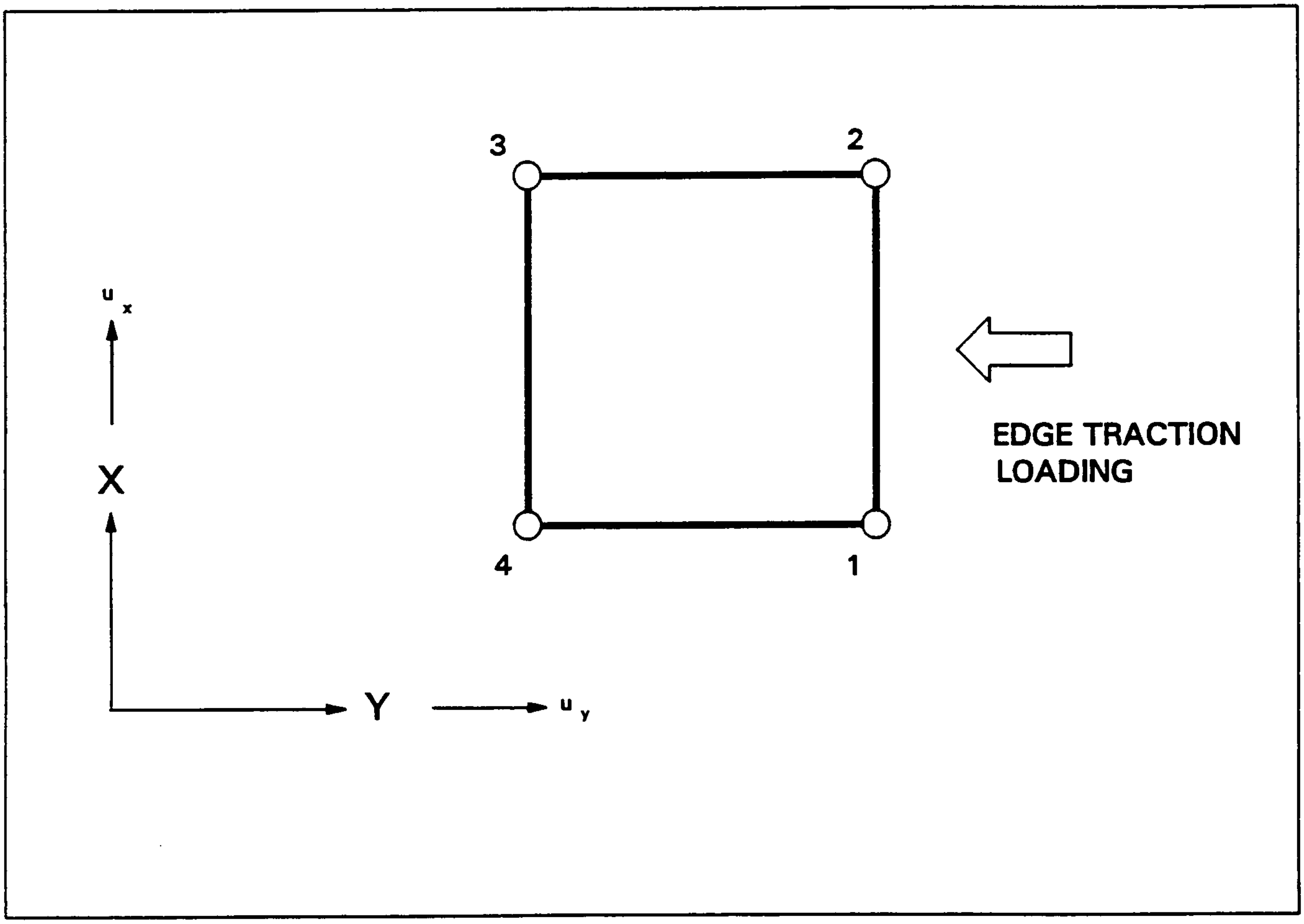

Figure 3.14: Plane Stress Element

3.3 TYPE OF ANALYSIS

There are four types of analyses available in HITCAN:

- Incremental static analysis with nonlinear anisotropic material behavior
- Dynamic analysis using direct time integration
- Modal analysis (free vibration)
- Buckling analysis (first critical buckling load).

The code will assume an incremental static analysis, unless the program option card DYNAMIC is specified. Note that for the static analysis no program option card or card groups are required. If a dynamic analysis is chosen by the user, four additional sets of data can be entered. They are:

- Initial accelerations at selected nodes
- Damping coefficients
- Initial displacements at selected nodes
- Initial velocities at selected nodes.

One of the most features of HITCAN is it's capability to generate a restart file. This feature is useful in two ways.
By using this feature the user can make several small runs instead of one large run, thus reducing turn around time. Secondly, if HITCAN fails to converge, a restart file is automatically generated. This enables the user to then continue the analysis at a smaller load increment.

The table below lists the analyses and the restart feature with their corresponding program option card and card groups.

TYPE OF ANALYSIS	OPTIONS	PROGRAM OPTIONS CARDS	CARD GROUPS
Static Dynamic		DYNAMIC	13
	Initial Acceleration	ACCELERATION	22 39
	Damping	DAMP	14
	Initial Displacements	DISPLACEMENT	20 37
	Initial Velocity	VELOCITY	21 38
Buckling		BUCKLE	11 44
Modal		MODAL	11 43
Restart		RESTART	10

DYNAMIC ANALYSIS

This option activates the direct time integration dynamic analysis. The integration scheme used is the Newmark-Beta method. For a description of this method, see Reference 7.

Program option cards: DYNAMIC

Card group: 13

Columns	Format	Variable Name	Entry
1st card			
1-4	I4	INCDYN	Number of load increments between updating of the material properties.

EXAMPLE:

Card Group 13

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1
```

Columns	Field Name	Value	Description
1-4	INCDYN	1	The material properties will be updated every load increment.

INITIAL ACCELERATION

This option enables the user to specify initial acceleration, at user-selected nodal points, for the direct time integration analysis. If this option is not specified, the initial accelerations are set to 0.

Program option card:	ACCELERATION
Card groups:	22 and 39

Columns	Format	Variable Name	Entry
1st card of card group 22			
1-4	I4	NACC	Number of acceleration data sets. Each data set can specify acceleration for all degrees of freedom at several nodal points with equal increment in their node numbers.
1st card of card group 39			
1-4	I4	IBEG	The first node number in this set of nodes.
5-8	I4	IEND	The last node in this set of nodes.
9-12	I4	INCR	Increment at which the node numbers are incremented.
2nd card of card group 39			
1-10	F10.4	ACELIN(1)	Initial acceleration for the 1st degree-of-freedom for this set of nodes.
11-20	F10.4	ACELIN(2)	Initial acceleration for the 2nd degree-of-freedom for this set of nodes.
21-30	F10.4	ACELIN(3)	Initial acceleration for the 3rd degree-of-freedom for this set of nodes.
31-40	F10.4	ACELIN(4)	Initial acceleration for the 4th degree-of-freedom for this set of nodes.
41-50	F10.4	ACELIN(5)	Initial acceleration for the 5th degree-of-freedom for this set of nodes.
51-60	F10.4	ACELIN(6)	Initial acceleration for the 6th degree-of-freedom for this set of nodes.

These two cards are repeated NACC times.

EXAMPLE:

Card Group 22

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1
```

Card Group 39

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   4   7   1
      10.0       0.0       0.0       0.0       0.0       0.0
```

Columns	Field Name	Value	Description
1-4	NACC	1	Number of initial acceleration data sets is 1.
1-4	IBEG	4	The 1st node in this series of nodes is 1.
5-8	IEND	7	Last node in this series of nodes is 7.
9-12	INCR	1	Increment at which the node numbers are incremented is 1.
1-10	ACELIN(1)	10.0	The 1st degree-of-freedom has an initial acceleration of 10.0 in./sec.^{2}
11-20	ACELIN(2)	0.0	The 2nd degree-of-freedom has an initial acceleration of 0.0 in./sec.^{2}
21-30	ACELIN(3)	0.0	The 3rd degree-of-freedom has an initial acceleration of 0.0 in./sec.^{2}
31-40	ACELIN(4)	0.0	The 4th degree-of-freedom has an initial acceleration of 0.0 in./sec.^{2}
41-50	ACELIN(5)	0.0	The 5th degree-of-freedom has an initial acceleration of 0.0 in./sec.^{2}
51-60	ACELIN(6)	0.0	The 6th degree-of-freedom has an initial acceleration of 0.0 in./sec.^{2}

DAMPING

This option defines damping for the direct time integration analysis. At the present time, only Rayleigh damping is available in HITCAN. Thus damping matrix [C] is of the form

$$[C] = a[M] + ß[K],$$

where a is the damping coefficient of the mass matrix [M] and ß is the damping coefficient of the stiffness matrix [K].

Program option card: DAMP

Card group: 14

Columns	Format	Variable Name	Entry
1st card			
1-8	F8.4	DAMPMS	Damping coefficient for the mass matrix.
9-16	F8.4	DAMPST	Damping coefficient for the stiffness matrix.

INITIAL DISPLACEMENT

This option enables the user to specify initial displacement, at user-selected nodal points, for the direct time integration analysis. If this option is not specified, the initial displacements are set to 0.

Program option card: DISPLACEMENT

Card groups: 20 and 37

Columns	Format	Variable Name	Entry
1st card of card group 20			
1-4	I4	NDIS	Number of displacement data sets. Each data set can specify displacement for all degrees of freedom at several nodal points with equal increment in their node numbers.
1st card of card group 37			
1-4	I4	IBEG	The first node number in this set of nodes.
5-8	I4	IEND	The last node in this set of nodes.
9-12	I4	INCR	Increment at which the node numbers are incremented.
2nd card of card group 37			
1-10	F10.4	DISPIN(1)	Initial displacement for the 1st degree-of-freedom for this set of nodes.
11-20	F10.4	DISPIN(2)	Initial displacement for the 2nd degree-of-freedom for this set of nodes.
21-30	F10.4	DISPIN(3)	Initial displacement for the 3rd degree-of-freedom for this set of nodes.
31-40	F10.4	DISPIN(4)	Initial displacement for the 4th degree-of-freedom for this set of nodes.
41-50	F10.4	DISPIN(5)	Initial displacement for the 5th degree-of-freedom for this set of nodes.
51-60	F10.4	DISPIN(6)	Initial displacement for the 6th degree-of-freedom for this set of nodes.

These two cards are repeated NDIS times.

EXAMPLE:

Card Group 22

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1
```

Card Group 39

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
  12  14   2
       0.0       0.0       5.0       0.0       0.0       0.0
```

Columns	Field Name	Value	Description
1-4	NACC	1	Number of initial acceleration data sets is 1.
1-4	IBEG	12	The 1st node in this series of nodes is 1.
5-8	IEND	14	Last node in this series of nodes is 14.
9-12	INCR	2	Increment at which the node numbers are incremented is 2.
1-10	DISPIN(1)	0.0	The 1st degree-of-freedom has an initial displacement of 0.0 in.
11-20	DISPIN(2)	0.0	The 2nd degree-of-freedom has an initial displacement of 0.0 in.
21-30	DISPIN(3)	5.0	The 3rd degree-of-freedom has an initial displacement of 5.0 in.
31-40	DISPIN(4)	0.0	The 4th degree-of-freedom has an initial displacement of 0.0 in.
41-50	DISPIN(5)	0.0	The 5th degree-of-freedom has an initial displacement of 0.0 in.
51-60	DISPIN(6)	0.0	The 6th degree-of-freedom has an initial displacement of 0.0 in.

INITIAL VELOCITY

This option enables the user to specify initial velocities, at user-selected nodal points, for the direct time integration analysis. If this option is not specified, the initial velocities are set to 0.

Program option card: VELOCITIES
Card groups: 21 and 38

Columns	Format	Variable Name	Entry
1st card of card group 21			
1-4	I4	NVEL	Number of velocity data sets. Each data set can specify the velocity for all degrees of freedom at several nodal points with equal increment in their node numbers.
1st card of card group 38			
1-4	I4	IBEG	The first node number in this set of nodes.
5-8	I4	IEND	The last node in this set of nodes.
9-12	I4	INCR	Increment at which the node numbers are incremented.
2nd card of card group 38			
1-10	F10.4	VELOIN(1)	Initial velocity for the 1st degree-of-freedom for this set of nodes.
11-20	F10.4	VELOIN(2)	Initial velocity for the 2nd degree-of-freedom for this set of nodes.
21-30	F10.4	VELOIN(3)	Initial velocity for the 3rd degree-of-freedom for this set of nodes.
31-40	F10.4	VELOIN(4)	Initial velocity for the 4th degree-of-freedom for this set of nodes.
41-50	F10.4	VELOIN(5)	Initial velocity for the 5th degree-of-freedom for this set of nodes.
51-60	F10.4	VELOIN(6)	Initial velocity for the 6th degree-of-freedom for this set of nodes.

These two cards are repeated NVEL times.

EXAMPLE:

Card Group 21

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1
```

Card Group 38

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   4   7   1
       1.0       0.0       0.0       0.0       0.0       0.0
```

Columns	Field Name	Value	Description
1-4	NVEL	1	Number of initial velocity data sets is 1.
1-4	IBEG	4	The 1st node in this series of nodes is 1.
5-8	IEND	7	Last node in this series of nodes is 7.
9-12	INCR	1	Increment at which the node numbers are incremented is 1.
1-10	VELOIN(1)	10.0	The 1st degree-of-freedom has an initial velocity of 1.0 in./sec.
11-20	VELOIN(2)	0.0	The 2nd degree-of-freedom has an initial velocity of 0.0 in./sec.
21-30	VELOIN(3)	0.0	The 3rd degree-of-freedom has an initial velocity of 0.0 in./sec.
31-40	VELOIN(4)	0.0	The 4th degree-of-freedom has an initial velocity of 0.0 in./sec.

Columns	Field Name	Value	Description
41-50	VELOIN(5)	0.0	The 5th degree-of-freedom has an initial velocity of 0.0 in./sec.
51-60	VELOIN(6)	0.0	The 6th degree-of-freedom has an initial velocity of 0.0 in./sec.

BUCKLING ANALYSIS

This option activates the buckling analysis. To determine the critical buckling load, MHOST uses the subspace iteration method. For a description of this method, see Reference 7. When this option is used, a buckling analysis is performed at the initial load and the times specified in the array TIMEMB.

Program option card: BUCKLE

Card groups: 11 and 44

Columns	Format	Variable Name	Entry
1st card of card group 11			
1-4	I4	NEIGV	Number of critical buckling modes to be extracted. At the present time this value should be set to 1.
5-8	I4	NSUBD	Number of subspace dimensions for the eigenvalue extraction. A sufficient dimension is reserved as a default.
9-12	I4	MHITER	Maximum number of iterations allowed in MHOST for the subspace iteration. The default for the maximum number of iterations is 5.
2nd card of card group 11			
1-8	F8.2	RESID	The allowable tolerance in MHOST. The default value is 5.0.
1st card of card group 43			
1-10	F10.6	TIMEMB	Times at which a buckling analysis is desired. A maximum of 8 times are allowed.

EXAMPLE:

Card Group 11

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
    1    0    10
     5.0
```

Card Group 43

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
      10.0
```

Columns	Field Name	Value	Description
1-4	NEIGV	1	Must be set to 1.
5-8	NSUBD	0	The default value is used.
9-12	MHITER	10	The allowable number of iterations in MHOST is set to 10.
1-8	RESID	5.0	The allowable tolerance in MHOST is set 5.0.
1-10	TIMEMB	10.0	A buckling analysis is desired at 10 sec.

MODAL ANALYSIS

When this option is used HITCAN will perform a free vibration dynamic analysis to determine the frequencies and the mode shapes. To determine the frequencies and the mode shapes, MHOST uses the subspace iteration method. For a description of this method, see Reference 7.

Program option card: MODAL

Card groups: 11 and 43

Columns	Format	Variable Name	Entry
1st card of card group 11			
1-4	I4	NEIGV	Number of modes to be extracted. At the present time this value should be set to 1.
5-8	I4	NSUBD	Number of subspace dimensions for the eigenvalue extraction. A sufficient dimension is reserved as a default.
9-12	I4	MHITER	Maximum number of iterations allowed in MHOST for the subspace iteration. The default for the maximum number of iterations is 5.
2nd card of card group 11			
1-8	F8.2	RESID	The allowable tolerance in MHOST. The default value is 5.0.
1st card of card group 43			
1-10	F10.6	TIMEMS	Times at which a modes are to be extracted. A maximum of 8 times are allowed.

EXAMPLE:

Card Group 11

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
    1    0   10
     5.0
```

Card Group 43

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
       5.0
```

Columns	Field Name	Value	Description
1-4	NEIGV	1	Must be set to 1.
5-8	NSUBD	0	The default value is used.
9-12	MHITER	10	The allowable number of iterations in MHOST is set to 10.
1-8	RESID	5.0	The allowable tolerance in MHOST is set 5.0.
1-10	TIMEMB	10.0	A buckling analysis is desired at 5 sec.

RESTART

This feature enables the user to conduct an analysis in several runs, an useful option for large problems. When the RESTART option is specified, a restart file created in a previous run is input. This file contains the necessary information to continue the analysis, including, the load step number, increment number, ply stresses, microstresses, microstress rates, material failure flags, and nodal displacements. For a restart run, the input is the same as before, except that RESTART is now specified in the program option cards.

A restart file is created by specifying the variable MSTART. MSTART is the number of increments to be preformed in a particular run. After the analysis has progressed through MSTART increments, a restart file is created and the run is terminated. Note that a restart file will also be created when the maximum number of allowable iterations (the variable MITER) in HITCAN is exceeded. Note that card group #10 must be entered whether or not the program option card RESTART is specified.

Program option card: RESTART

Card group: 10

Columns	Format	Variable Name	Entry
1st card in card group 10			
1-4	I4	NTISTP	Number of load steps.
5-8	I4	NMECH	Number of mechanical cycles used in METCAN to account for cyclic damage (used for fatigue analysis).
9-12	I4	NTHER	Number of thermal cycles used in METCAN to account for cyclic damage (used for fatigue analysis).
13-16	I4	LINC	Number of load increments between load steps, see following figure.
17-20	I4	MSTART	Write a restart file after this many load increments.
21-24	I4	MITER	Maximum number of iterations allowed for global convergence per load increment.

Columns	Format	Variable Name	Entry
2nd card			
1-8	F8.4	TOL	Allowable global tolerance on convergence

EXAMPLE:

Card Group 10

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1   1   1   1   2  10
     1.0
```

Columns	Field Name	Value	Description
1-4	NTISTP	1	Number of load steps is 1.
5-8	NMECH	1	Number of mechanical cycles is 1.
9-12	NTHER	1	Number of thermal cycles is 1.
13-16	LINC	1	Number of load increments is 1.
17-20	MSTART	2	Write a restart file after 2 load increments.
21-24	MITER	10	Number of allowable iterations for global convergence.
1-8	TOL	1.0	Tolerance on the global convergence is 1.0.

3.4 MATERIAL DATA

In this section, the necessary program option cards and card groups used in building the composite model from constituent properties are described. The user builds the composite model by defining the plies over the surface of the structure and through the thickness. This produces an integrated laminated model of the entire structure.

The user has the flexibility of selecting the number of plies, the ply thickness, the fiber volume ratio, the void volume ratio, and the fiber orientation in building either a symmetric or an unsymmetric ply layup. When PLYORDER is used in conjunction with the program option card, UNSYMMETRICAL, the user can generate an unsymmetric ply layup. However, when the HPLATE model option is specified, only symmetric ply layups can be used.

Each ply is referred to by a designation number determined by the order in which it is listed in the input. A different ply designation number must be assigned if any one or more of the following variables; material properties, ply thickness, fiber volume ratio, void volume ratio, and fiber orientation, are different. However, a ply used more than once, but with same value to all of these variables, can be assigned only one ply designation number.

For a symmetric ply layup, the ply order is assumed to be from the bottom surface of the structure to the mid-thickness line moving in the positive y or z directions. This order is then reversed and the ply layup is then continued from the mid-thickness line to the opposite surface of the wall. If the ply layup is unsymmetric, i. e., the program option card UNSYMMETRICAL is specified, the ply layup is input in two parts. The first part is the ply layup from the bottom surface of the structure to the mid-thickness line moving in the positive y or z directions. The second part is the ply order from the opposite surface to the mid-thickness line moving in the negative y or z directions.

The ply orientation angle, measured in degrees, is defined from the HITCAN global x-axis to be positive in the positive x-y quadrant for the SPLATE, HPLATE, S3DSOLID, and READ IN MODEL options. For the spars of the HPLATE model option the angle is positive in the positive x-z quadrant. Figure 3.15 illustrates the composite geometry relative to the HITCAN coordinate system. Note at the present time only one ply description is allowed for each spar. A sufficient number of these plies will be generated to fill the spar thickness. The orientation of the fibers in these plies will be along the x-axis.

To account for the existence of a discrete interphase between the fiber and the matrix, the user is allowed to enter the interphase thickness as a fraction of the fiber diameter. This is done by specifying the program option card INTERPHASE and entering value of the variable PINTER in card group 23.

In creating this section of input, the card groups 1 and 28 must always be specified. These two card groups contain the necessary data to describe the plys. The program option cards PLYORDER and UNSYMMETRICAL can be used only with the model options HPLATE, SPLATE, and S3DSOLID. For the model option READ IN MODEL, the user must use card groups 12 and 31. The table below summarizes the program option cards and card groups used in this section.

	PROGRAM OPTION CARDS	CARD GROUPS	COMMENTS
Ply Description Data		1 28	This data is needed for all model options.
Symmetrical Ply Order	PLYORDER	6 29	Use for SPLATE, HPLATE, & S3DSOLID model options.
Unsymmetrical Ply Order	PLYORDER UNSYMMETRICAL	7 30	Use for SPLATE, & S3DSOLID model options.
Ply Layup Specified at Each Node		8 12 31	Use for the model option READ IN model.
Interphase Data	INTERFACE	23	Used only if an interface between the fiber and matrix is to be modelled.

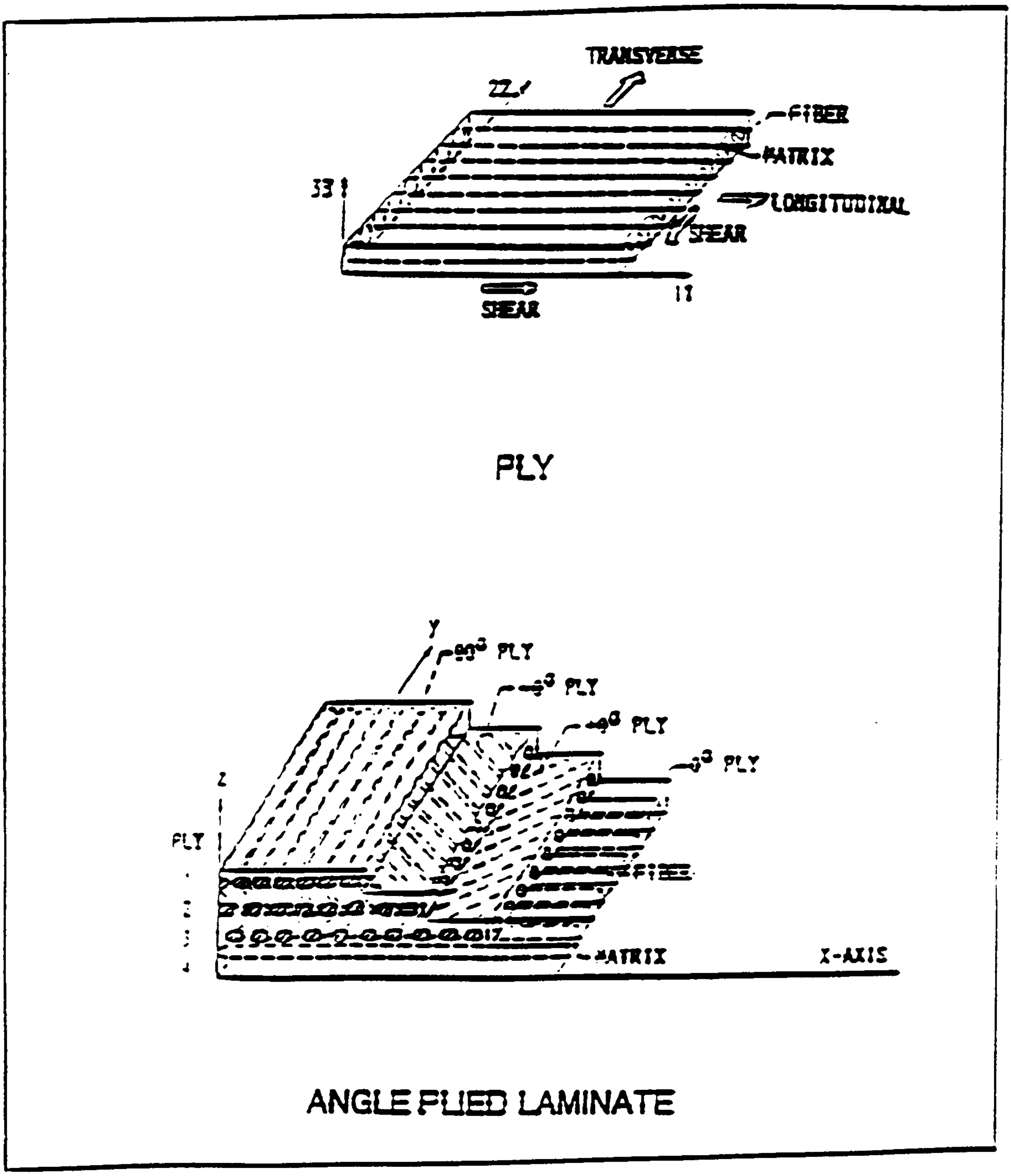

Figure 3.15: Fiber Composite Geometry Relative To HITCAN Coordinate System

PLY DESCRIPTION CARDS

These cards contain the necessary data to describe each unique ply in the structure. These card groups are required for all model options.

Program option card: None

Card group: 1 and 28

Columns	Format	Variable Name	Entry
1st card in card group 1			
1-4	I4	NDES	Number of ply descriptions.
1st card in card group 28			
1-10	F10.4	PERT(1)	Initial thickness (percent of thickness at each input point).
11-20	F10.4	PERT(2)	Final thickness (percent of thickness at each input point).
1-30	F10.4	PERT(3)	Initial x coordinate (percent length).
1-40	F10.4	PERT(4)	Final x coordinate (percent length).
41-50	F10.4	PERT(5)	Initial y coordinate (percent width).
51-60	F10.4	PERT(6)	Initial y coordinate (percent width).
2nd card in card group 28			
1-4	A4	CODES(1)	Type of fiber.
5	1X		
6-9	A4	CODES(2)	Type of matrix.
10	1X		
11-20	F10.4	CODES(3)	Ply thickness.
21-30	F10.4	CODES(4)	Void volume ratio.
31-40	F10.4	CODES(5)	Fiber volume ratio.
41-50	F10.4	CODES(6)	Ply orientation angle.

These two cards are required for each ply description, thus these cards are repeated NDES times. Ply designation numbers are assigned in the order in which the ply descriptions are listed.

EXAMPLE:

Card Group 1

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1
```

Card Group 28

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
       0.0     100.0       0.0      100.       0.0     100.0
SICA TI15        0.2       0.0       0.5      45.0
```

Columns	Field Name	Value	Description
1-4	NDES	1	The number of plys to be described is 1.
1-10	PERT(1)	0.0	The initial thickness is 0.0% of the thickness at each input point.
11-20	PERT(2)	100.0	The final thickness is 100.0% of the thickness at each input point.
21-30	PERT(3)	0.0	The initial x coordinate of the ply is at 0.0% of the length at each input point.
31-40	PERT(4)	100.0	The final x coordinate of the ply is at 100.0% of the length at each input point.
41-50	PERT(5)	0.0	The initial y coordinate of the ply is at 0.0% of the width at each input point.
51-60	PERT(6)	100.0	The final y coordinate of the ply is at 100.0% of the width at each input point.
1-4	CODES(1)	SICA	The fiber material is designated in the databank as SICA.
6-9	CODES(2)	TI15	The matrix material is designated in the databank as T115.
11-20	CODES(3)	0.2	The ply thickness is 0.2 in.
21-30	CODES(4)	0.0	The void volume ratio is 0.0.
31-40	CODES(5)	0.5	The fiber volume ratio is 0.5.
41-50	CODES(6)	45.0	The fiber orientation angle is 45 degrees.

PLY LAYUP FOR A SYMMETRICAL PLYORDER

This program option card allows the user to create a symmetrical ply layup. When PLYORDER is used in conjunction with the program option card, UNSYMMETRICAL, the user can generate an unsymmetric ply layup. However, when the HPLATE model option is specified, only symmetric ply layups can be used.

Program option card: PLYORDER

Card group: 6 and 29

Columns	Format	Variable Name	Entry
1st card in card group 6			
1-4	I4	MAXPLY	Number of plies specified for the half-thickness at the point of maximum wall thickness in the structure for the model options HPLATE, SPLATE, and S3DSOLID.
1st card in card group 29			
1-80	20I4	MPLY	An array containing the ply order, using ply designation numbers, for one half of the wall thickness. The order is from the bottom surface to the mid-thickness line moving in the positive y or z directions.

EXAMPLE:

Card Group 6

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   2
```

Card Group 29

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1   1
```

Columns	Field Name	Value	Description
1-4	MAXPLY	2	There are two plys from the bottom surface to the mid-thickness line.
1-4	MPLY(1)	1	The 1st ply up from the bottom surface has the designation number of 1.
5-8	MPLY(2)	1	The 2nd ply up from the bottom surface has the designation number of 1.

PLY LAYUP FOR AN UNSYMMETRICAL PLYORDER

This option specifies an unsymmetric ply layup. This option is to be used in conjunction with the PLYORDER program option card.

Program option card:	UNSYMMETRICAL PLYORDER and PLYORDER
Card group:	7 and 30

Columns	Format	Variable Name	Entry
1st card of card group 7			
1-4	I4	LMAX	Number of plies specified for the half-thickness at the point of maximum wall thickness in the structure for the model options SPLATE and S3DSOLID.
2nd card of card group 30			
1-80	20I4	NPLY	An array containing the ply order, using ply designation numbers, for one half of the wall thickness. The order is from the top surface to the mid-thickness line moving in the negative y or z directions.

EXAMPLE:

Card Group 7

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   2
```

Card Group 30

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1   2
```

Columns	Field Name	Value	Description
1-4	MAXPLY	2	There are two plys from the bottom surface to the mid-thickness line.
1-4	MPLY(1)	1	The 1st ply up from the mid-thickness line has the designation number of 1.
5-8	MPLY(2)	2	The 2nd ply up from the mid-thickness line has the designation number of 1.

PLY LAYUP FOR READ IN MODEL OPTION

This option enables the user to enter a ply layup for the READ IN MODEL option.

Program option card: None

Card group: 8, 12, and 31

Columns	Format	Variable Name	Entry
1st card of card group 8			
1-4	I4	MAXPLY	Maximum number of plies at any one node.
1st card in card group 12			
1-4	I4	NPLSET	Number of data sets describing the ply layup at each node.
1st card in card group 31			
1-4	I4	IBEG	The first node number in this set of nodes.
5-8	I4	IEND	The last node number in this set of nodes.
9-12	I4	INCR	Increment at which the node numbers are incremented.
13-16	I4	NOP	Number of plies at these nodes.
2nd card of card group 31			
1-80	20I4	MPLY	An array containing the ply order, using ply designation numbers, for one half of the wall thickness. The order is from the bottom surface to the mid-thickness line moving in the positive y or z directions.

These 2 cards are repeated NPLSET times.

EXAMPLE:

Card Group 8

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   3
```

Card Group 12

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1
```

Card Group 31

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1  16   1   3
   1   2   1
```

Columns	Field Name	Value	Description
1-4	MAXPLY	2	The maximum number of plies is 3.
1-4	NPLSET	1	One data set is used to describe the ply layup or each node in the model.
1-4	IBEG	1	The 1st node in this series of nodes is 1.
5-8	IEND	16	The last node in this series of nodes is 16.
9-12	INCR	1	The increment between node numbers is 1.
13-16	NOP	3	The number of plies to be read in is 3.
1-4	MPLY(1)	1	The 1st ply up from the bottom surface line has the designation number of 1.
5-8	MPLY(2)	2	The 2nd ply up from the bottom surface has the designation number of 2.
9-12	MPLY(3)	1	The 3rd ply up from the bottom surface has the designation number of 1.

INTERPHASE DATA

This option enables the user to specify the existence of a discrete interphase between the fiber and the matrix. The thickness of the interphase is specified as a fraction of the fiber diameter, i.e., Pinter = $(D_o - D)/D_o$, where D_o represents the initial fiber diameter and D the fiber diameter after degradation.

Program option card: INTERPHASE

Card group: 23

Columns	Format	Variable Name	Entry
1st card of card group 23			
1-8	F8.4	PINTER	Thickness of the interphase as a fraction of fiber diameter.

EXAMPLE:

Card Group 23

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
       0.1
```

Columns	Field Name	Value	Description
1-8	PINTER	.1	The thickness of the interphase is .1 x fiber diameter.

3.5 TYPES OF LOADING

There are four types of loading available in HITCAN. They are:

Centrifugal,
Nodal Forces,
Pressure,
Temperature.

Each loading type has its own program option card and card groups. Along with the program option cards and card groups associated with the different loadings, additional card groups are needed for program control. The following table summarizes the different loadings and their program option cards and card groups.

LOADING TYPE	PROGRAM OPTION CARD	CARD GROUP
Centrifugal	ANGULAR	35
Nodal Forces	FORCE	15 36 16
Pressure	PRESSURE	33 34
Temperature	TEMPERATURE	17 33 34
Program Control		10 32

CENTRIFUGAL LOADING

This option defines a centrifugal distributed loading.

Program option card: ANGULAR

Card group: 35

Columns	Format	Variable Name	Entry
1st card			
1-30	3F10.4	GRIDP1	The first of two points required to define the axis of rotation. See Figure 3.16, for the direction of this axis. GRIDP1 is an array of three real numbers. The first real number is the x coordinate, the second is the y coordinate, and the third real number is the z coordinate.
31-60	3F10.4	GRIDP2	The second of two points required to define the axis of rotation. GRIDP2 is an array of three real numbers. The first real number is the x coordinate, the second is the y coordinate, and the third real number is the z coordinate.
2nd card			
1-80	8F10.4	ANGVEL	Rotational speed in revolutions per second at each time step.

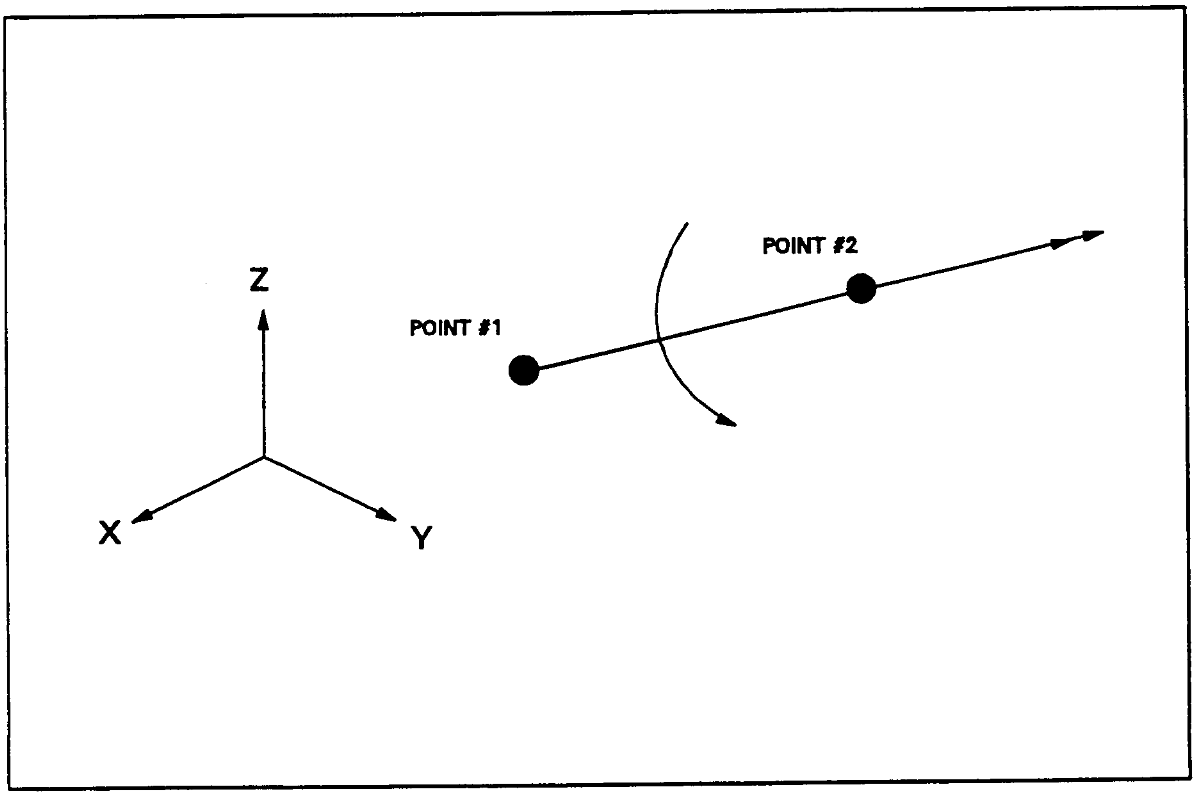

Figure 3.16: Direction Of Axis For Centrifugal Loading

EXAMPLE:

Card Group 35

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
       0.0       0.0       0.0       1.0       0.0       0.0
     100.0
```

Columns	Field Name	Value	Description
1-10	GRIDP1(1)	0.0	X-coordinate
11-20	GRIDP1(2)	0.0	Y-coordinate
21-30	GRIDP1(3)	0.0	Z-coordinate
31-40	GRIDP2(1)	1.0	X-coordinate
41-50	GRIDP2(2)	0.0	Y-coordinate
51-60	GRIDP2(3)	0.0	Z-coordinate
1-10	ANGVEL(1)	100.0	The rotational velocity in rad/sec.

NODAL FORCE LOADING

This option allows the user to input static concentrated nodal loads.

Program option card: FORCE

Card groups: 15 and 36

Columns	Format	Variable Name	Entry
1st card in card group 15			
1-4	I4	NCFOR	Number of nodal loads
1st card in card group 36			
1-4	I4	NCFNOD	Node number
5-8	I4	NCFDIR	Degree-of-freedom
2nd card in card group 36			
1-80	8F10.4	CFVAL	Value of the load at each load step

Card group 36 is repeated NCFOR times.

EXAMPLE:

Card Group 15

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1
```

Card Group 36

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1   1
      10.
```

Columns	Field Name	Value	Description
1-4	NCFOR	1	Number of nodal forces is 1.
1-4	NCFNOD	1	The force acts at node #1.
5-8	NCFDIR	1	The force acts along the X-axis.
1-10	CFVAL	10.0	The intensity of the load.

PRESSURE LOADING

This card set allows the user to input the pressure loading. For either solid or hollow structures using the plate element, the user can specify both a lateral pressure and an uniform edge pressure. For the plane stress, plane strain, and 3D solid elements only an uniform edge pressure can be specified. Note that if PL and PU are used to input the pressure loading the variables TL and TU must also be specified. If temperature effects are not desired, then TL and TU must be set to 0.0

The pressure is entered using one of the following three options:

A. When the SPLATE model option is specified.

B. When the HPLATE model option is specified.

C. When the S3DSOLID model or the READ IN MODEL options are specified.

Program option card: PRESSURE

Card groups: 16, 33, and 34

Columns	Format	Variable Name	Entry
1st card in card group 16			
1-4	I4	NPRES	Number of pressure input data sets. These data sets specify those elements which have a normal surface pressure (positive into the element).

Option A

card 1a in card group 33

Columns	Format	Variable Name	Entry
1-10	F10.4	TL	Temperature on the lower surface.
11-20	F10.4	TU	Temperature on the upper surface.
21-30	F10.4	PL	Pressure on the lower surface.
31-40	F10.4	PU	Pressure on the upper surface.

This card is repeated (MSECT(1) + MSECT(2) +...+ MSECT(I))*NTISTP times, where I=1,NSECT.

Columns	Format	Name	Entry

Option B
card 1b in card group 33

1-10	F10.4	TL	Temperature on the lower surface.
11-20	F10.4	TU	Temperature on the upper surface.
21-30	F10.4	PU	Pressure on the lower surface.
31-40	F10.4	PL	Pressure on the upper surface.

Note that each card corresponds to an input point, thus, this card is repeated (MSECT(1,1) + MSECT(2,1) +...+ MSECT(I,1))*NTISTP times, where I=1,LSECT(1).

card 2b in card group 33

1-10	F10.4	TL	Temperature on the lower surface.
11-20	F10.4	TU	Temperature on the upper surface.
21-30	F10.4	PU	Pressure on the lower surface.
31-40	F10.4	PL	Pressure on the upper surface.

Note that each card corresponds to an input point, thus, this card is repeated (MSECT(1,2) + MSECT(2,2) +...+ MSECT(I,2))*NTISTP times, where I=1,LSECT(2).

card 3 in card group 33

1-4	I4	IBEG	The first node number in this set of nodes.
5-8	I4	IEND	The last node in this set of nodes.
9-12	I4	INCR	Increment between node numbers.

card 4 in card group 33

1-80	F10.4	PREVAL	An array containing the intensity of the edge pressure at each load step.

Cards 3 and 4 are repeated NPRES times.

Option C
card 3 in card group 34

1-4	I4	IBEG	Beginning element number.
5-8	I4	IEND	Ending element number.
9-12	I4	INCR	Increment between element numbers.

card 4 in card group 34

1-80	F10.4	PREVAL	An array containing the intensity of the edge pressure at each load step.

Cards 3 and 4 are repeated NPRES times.

Cards 3 and 4 are repeated NPRES times.

EXAMPLE:

Card Group 16
```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1
```

Card Group 33
```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
      70.0      70.0       0.0      10.0
      70.0      70.0       0.0      10.0
      70.0      70.0       0.0      20.0
      70.0      70.0       0.0      20.0
```

Card Group 34
```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1   4   1
      10.0
```

Columns	Field Name	Value	Description
1-4	NPRES	1	There is 1 set of data to describe the edge loads.
1-10	TL	70.0	Temperature on the lower surface at input point #1 of input section #1.
11-20	TU	70.0	Temperature on the lower surface at input point #1 of input section #1.
21-30	PL	0.0	Pressure on the lower surface at input point #1 of input section #1.
31-40	PU	10.0	Pressure on the upper surface at input point #1 of input section #1.
1-10	TL	70.0	Temperature on the lower surface at input point #2 of input section #1.
11-20	TU	70.0	Temperature on the lower surface at input point #2 of input section #1.
21-30	PL	0.0	Pressure on the lower surface at input point #2 of input section #1.
31-40	PU	10.0	Pressure on the upper surface at input point #2 of input section #1.
1-10	TL	70.0	Temperature on the lower surface at input point #1 of input section #2.
11-20	TU	70.0	Temperature on the lower surface at input point #1 of input section #2.
21-30	PL	0.0	Pressure on the lower surface at input point #1 of input section #2.

Columns	Field Name	Value	Description
31-40	PU	20.0	Pressure on the upper surface at input point #1 of input section on #2.
1-10	TL	70.0	Temperature on the lower surface at input point #2 of section #2.
11-20	TU	70.0	Temperature on the lower surface at input point #2 of input section #2.
21-30	PL	0.0	Pressure on the lower surface at input point #2 of input section #2.
31-40	PU	20.0	Pressure on the upper surface at input point #2 of input section #2.
1-4	IBEG	1	The edge load is applied to elements
1			through 4.
5-8	IEND	4	
9-12	INCR	1	
1-10	PREVAL	10.0	The intensity of the edge load.

TEMPERATURE LOADING

This card set allows the user to input a distributed temperature loading. Note that if TL and TU are used to input the temperature loading the variables PL and PU must also be specified. If there is no lateral pressure loading, then PL and PU should be set 0.0. The ply temperatures generated by TL and TU will be overridden by the ply temperatures contained in the variable TEPLY. The temperature is entered using one of the following three options:

A. When the SPLATE model option is specified.

B. When the HPLATE model option is specified.

C. When the S3DSOLID model or the READ IN MODEL options are specified.

Program option card: TEMPERATURE

Card groups: 17, 33, and 34

Columns	Format	Variable Name	Entry
1st card in card group 17			
1-4	I4	NTEMP	Number of temperature input data sets. These data sets be can used either to specify the temperature at the nodes (READ IN MODEL or S3DSOLID model options) or at the plies at each node (HPLATE or SPLATE model options).
5-8	I4	NUMPLY	The maximum number of plies in a data set.

Columns	Format	Variable Name	Entry

Option A

card 1a in card group 33

1-10	F10.4	TL	Temperature on the lower surface.
11-20	F10.4	TU	Temperature on the upper surface.
21-30	F10.4	PL	Pressure on the lower surface.
31-40	F10.4	PU	Pressure on the upper surface.

Note that each card corresponds to an input point, thus, this card is repeated (MSECT(1) + MSECT(2) +...+ MSECT(I))*NTISTP times, where I=1,NSECT.

Option B

card 1b in card group 33

1-10	F10.4	TL	Temperature on the lower surface.
11-20	F10.4	TU	Temperature on the upper surface.
21-30	F10.4	PU	Pressure on the lower surface.
31-40	F10.4	PL	Pressure on the upper surface.

This card is repeated (MSECT(1,1) + MSECT(2,1) +...+ MSECT(I,1))* NTISTP times, where I=1,LSECT(1).

card 2b in card group 33

1-10	F10.4	TL	Temperature on the lower surface.
11-20	F10.4	TU	Temperature on the upper surface.
21-30	F10.4	PU	Pressure on the lower surface.
31-40	F10.4	PL	Pressure on the upper surface.

This card is repeated (MSECT(1,2) + MSECT(2,2) + ... + MSECT(I,2))*NTISTP times, where I=1,LSECT(2).

card 3 in card group 33

1-4	I4	IBEG	The first node number in this set of nodes.
5-8	I4	IEND	The last node in this set of nodes.
9-12	I4	INCR	Increment between node numbers.

card 4 in card group 33

1-80	F10.4	TEPLY	Array of ply temperatures at each ply for each time step.

Cards 3 and 4 are repeated NTEMP times.

card 3 in card group 34

1-4	I4	IBEG	Beginning node number.
5-8	I4	IEND	Ending node number.
9-12	I4	INCR	Increment between node numbers.

card 4 in card group 34

1-80	F10.4	TENOD	Array of nodal temperatures at each node in the data set for each load step.

Cards 3 and 4 are repeated NTEMP times.

EXAMPLE:

Card Group 33

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
      70.0      70.0       0.0       0.0
      70.0      70.0       0.0       0.0
     100.0     100.0       0.0       0.0
     100.0     100.0       0.0       0.0
```

Columns	Field Name	Value	Description
1-10	TL	70.0	Temperature on the lower surface at input point #1 of input point section #1.
11-20	TU	70.0	Temperature on the lower surface at input point #1 of input section #1.
21-30	PL	0.0	Pressure on the lower surface at input point #1 of input section #1.
31-40	PU	0.0	Pressure on the upper surface at input point #1 of input section #1.
1-10	TL	70.0	Temperature on the lower surface at input point #2 of input section #1.
11-20	TU	70.0	Temperature on the lower surface at input point #2 of input section #1.
21-30	PL	0.0	Pressure on the lower surface at input point #2 of input section #1.
31-40	PU	0.0	Pressure on the upper surface at input point #2 of input section #1.

Columns	Field Name	Value	Description
1-10	TL	100.0	Temperature on the lower surface at input point #1 of input section #2.
11-20	TU	100.0	Temperature on the lower surface at input point #1 of input section #2.
21-30	PL	0.0	Pressure on the lower surface at intp point #1 of input section #2.
31-40	PU	0.0	Pressure on the upper surface at input point #1 of input section #2 .
1-10	TL	100.0	Temperature on the lower surface at input point #2 of input section #2.
11-20	TU	100.0	Temperature on the lower surface at input point #2 of input section #2.
21-30	PL	0.0	Pressure on the lower surface at input point #2 of input section #2 .
31-40	PU	0.0	Pressure on the upper surface at input point #2 of input section #2.

PROGRAM CONTROL CARDS

These cards are required to increment the loading.

Program option card: None

Card group: 10 and 32

Columns	Format	Variable Name	Entry
1st card in card group 10			
1-4	I4	NTISTP	Number of load steps.
5-8	I4	NMECH	Number of mechanical cycles used in METCAN to account for cyclic damage (used for fatigue analysis).
9-12	I4	NTHER	Number of thermal cycles used in METCAN to account for cyclic damage (used for fatigue analysis).
13-16	I4	LINC	Number of load increments between load steps, see Figure 3.17.
17-20	I4	MSTART	Write a restart file after this many load increments.
21-24	I4	MITER	Maximum number of iterations allowed for global convergence per load increment.
2nd card			
1-8	F8.4	TOL	Allowable global tolerance on convergence.
1st card in card group 32			
1-80	8F10.4	TISTPS	Time at load steps.

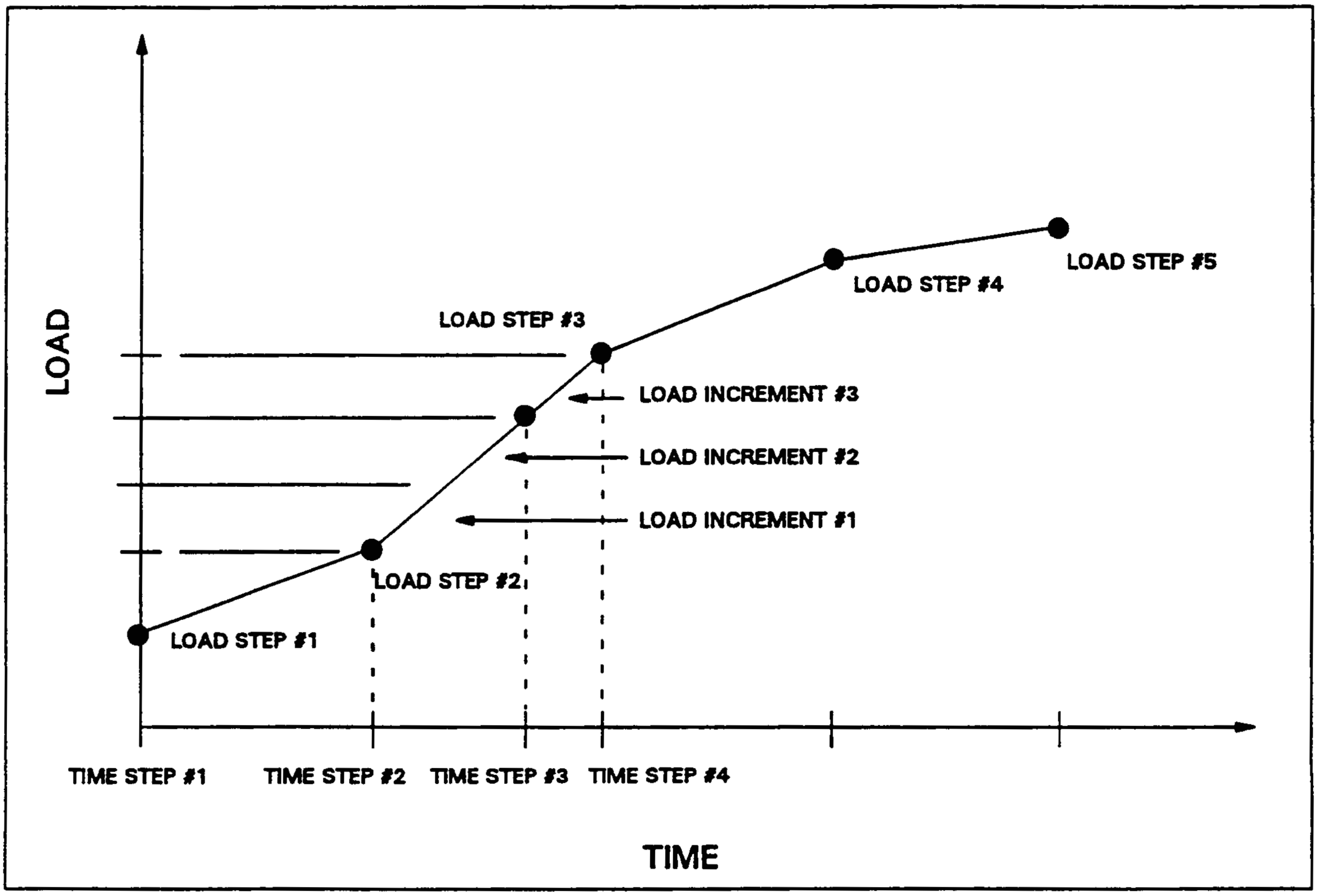

Figure 3.17: Definition Of The Load Increment

EXAMPLE:

Card Group 10

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1   1   1   1   2  10
     1.0
```

Card Group 32

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
       0.0
```

Columns	Field Name	Value	Description
1-4	NTISTP	1	Number of load steps is 1.
5-8	NMECH	1	Number of mechanical cycles is 1
9-12	NTHER	1	Number of thermal cycles is 1.
13-16	LINC	1	Number of load increments is 1.
17-20	MSTART	2	Write a restart file after 2 load increments.
21-24	MITER	10	Number of allowable iterations for global convergence.
1-8	TOL	1.0	Tolerance on the global convergence is 1.0.
1-10	TISTPS(1)	0.0	Time at load step #1 is 0.0.

3.6 BOUNDARY CONDITIONS

In this section, the necessary program option cards and card groups used to describe the boundary conditions are given. To enter the boundary conditions, card groups 19 and 41 are used. If the skewed boundary conditions are required in the analysis, coordinate transformations are available. This option requires the program option card TRANSFORMATION and the card groups 18 and 40.

BOUNDARY CONDITIONS

These cards are required to enter the boundary conditions.

Program option card: None

Card group: 19 and 41

Columns	Format	Variable Name	Entry
1st card in card group 19			
1-4	I4	NBC	Number of boundary condition data sets.
1st card in card group 41			
1-4	I4	IBEG	Beginning node number.
5-8	I4	IEND	Ending node number.
9-12	I4	INCR	Increment at which the nodes in this series are incremented.
13-16	I4	IDOF	Degree-of-freedom which is fixed.

This card is repeated NBC times.

EXAMPLE:

Card Group 19

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1
```

Card Group 41

```
        1         2         3         4         5         6
1.......0.........0.........0.........0.........0.........0
   1  10   1   3
```

Columns	Field Name	Value	Description
1-4	NBC	1	One data set is chosen to describe the boundary conditions.
1-4	IBEG	1	The 1st node in this series of nodes is 1.
5-8	IEND	10	The last node in this series of nodes is 10.

Columns	Field Name	Value	Description
9-12	INCR	1	The increment between node numbers is 1.
13-16	IDOF	3	The 3rd degree-of-freedom is fixed.

COORDINATE TRANSFORMATION

Allows the user to specify a coordinate transformation of the global coordinate system into a local coordinate system at specified nodes. If more than one rotation is applied at a node, HITCAN executes all the entered rotations successively. This feature can be used to obtain transformations around an arbitrary axis. Each subsequent rotation acts upon the last previous coordinate system defined at the node. Note that this option follows the right hand coordinate system.

Program option card: TRANSFORMATION

Card group: 18 and 40

Columns	Format	Variable Name	Entry
1st card in card group 18			
1-4	I4	NTR	Number of coordinate transformation data sets.
1st card in card group 40			
1-4	I4	IBEG	First node in this set of nodes.
5-8	I4	IEND	Last node in this set of nodes.
9-12	I4	INCR	Increment at which nodes in this set of nodes are to be incremented.
13-16	I4	IDIR	Global axis about which the coordinates are rotated.
2nd card in card group 40			
1-10	F10.4	TRANG	Angle over which the coordinate system is rotated.

The cards in card group 40 are repeated NTR times.

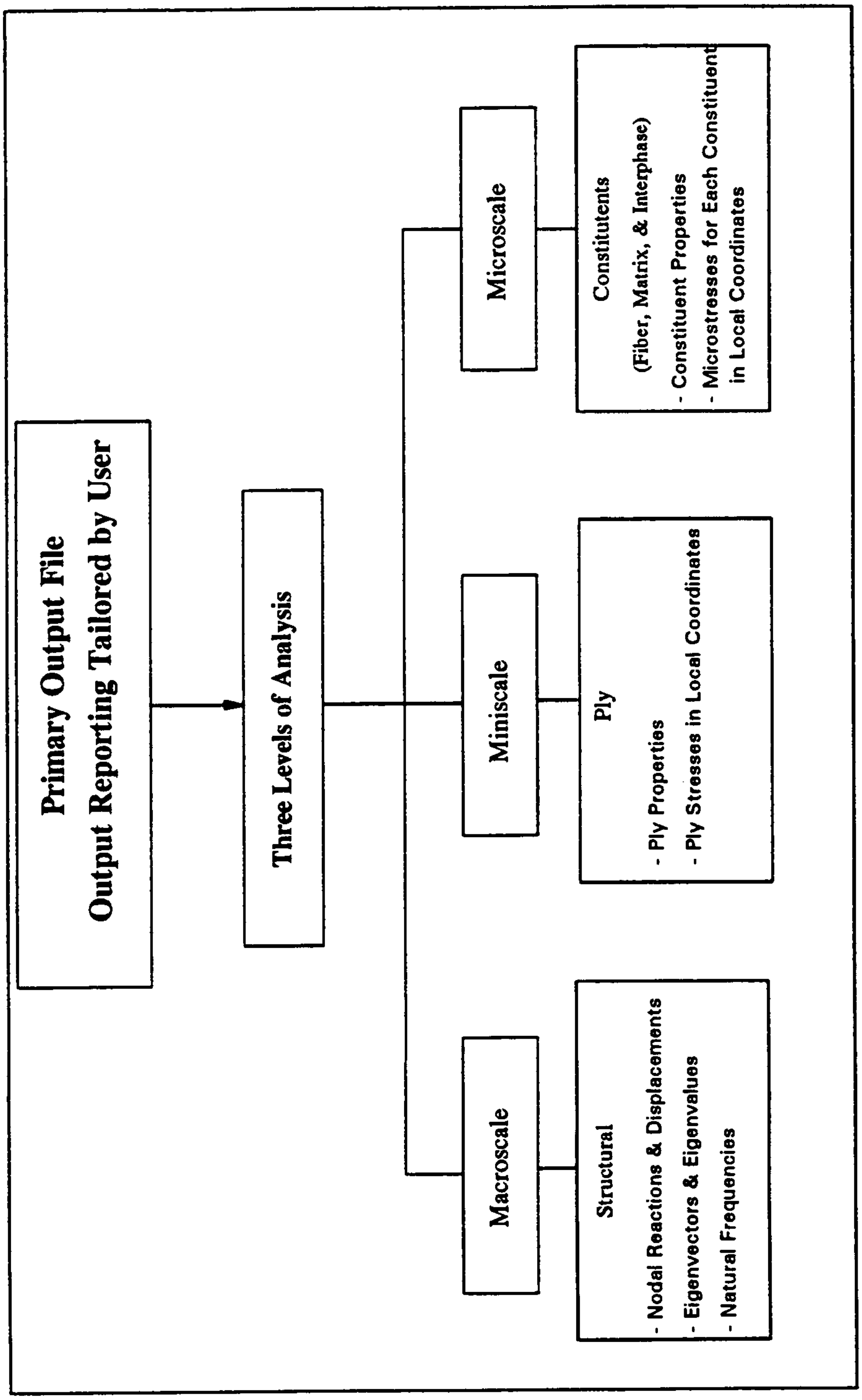

Figure 3.18 : The Different Levels of Analysis Results Available In The Primary Output File

OUTPUT CONTROL

Program option card: None

Card group: 42

Columns	Format	Variable Name	Entry
1st card in card group 42			
1-4	I4	NPRT(1,1)	Initial node for nodal displacements, velocities, and accelerations of set 1.
5-8	I4	NPRT(2,1)	Final node for nodal displacements, velocities, and accelerations of set 1.
9-12	I4	NPRT(1,2)	Initial node for nodal displacements, velocities, and accelerations of set 2.
13-16	I4	NPRT(2,2)	Final node for nodal displacements, reactions, velocities, and accelerations of set 2.
Etc.			Etc. in I4 format.
2nd card in card group 42			
1-4	I4	NPRTS(1,1)	Initial node for ply stress output of set 1.
5-8	I4	NPRTS(2,1)	Final node for ply stress output of set 1.
9-12	I4	NPRTS(1,2)	Initial node for ply stress output of set 2.
13-16	I4	NPRTS(2,2)	Final node for ply stress output of set 2.
Etc.			Etc. in I4 format.
3rd card in card group 42			
1-4	I4	NPRTP(1,1)	Initial node for constituent properties and stresses of set 1.
5-8	I4	NPRTP(2,1)	Final node for constituent properties and stresses of set 1.
9-12	I4	NPRTP(1,2)	Initial node for constituent properties and stresses of set 2.
13-16	I4	NPRTP(2,2)	Final node for constituent properties and stresses of set 2.
Etc.			Etc. in I4 format.

Columns	Field Name	Value	Description
1-4	NPRTP(1,1)	41	First node in the 1st series of nodal constituent properties and stresses is 41.
5-8	NPRTP(2,1)	41	Last node in the 1st series of nodal constituent properties and stresses is 41.
1-4	NPPLY(1,1)	1	First ply in the 1st series of ply constituent properties and stresses is 1.
5-8	NPPLY(2,1)	4	Last ply in the 1st series of ply constituent properties and stresses is 4.
1-10	TIMEPN	10.0	A PATRAN results file is desired at 10.0 sec.

3.8 PROGRAM OPTION CARDS

There are 29 program option cards. The option cards either control the flow through the program or activate various card groups. These cards are listed and summarized below in alphabetical order.

ACCELERATION

ANGULAR

BRICK

BUCKLE

DAMP

DISPLACEMENT

DYNAMIC

ECHO

ENDOPTION

FE MODEL ONLY

FORCE

HPLATE

INTERPHASE

MODAL

PLATE

PLYORDER

PRESSURE

PROFILE

READ IN MODEL

RESTART

S3DSOLID

SPLATE

STRAIN

STRESS

TEMPERATURE

TITLE

TRANSFORMATION

UNSYMMETRICAL PLYORDER

VELOCITY

The HPLATE, S3DSOLID, and the SPLATE option cards determine the type of finite element model to be generated by HITCAN. The READ IN MODEL option enables the user to input into HITCAN a finite element model consisting of eight node solid elements. One of these four cards must be included in the "Program Option Cards" block of the input deck.

The ENDOPTION card is required to designate the end of the "Program Option Cards". Note that only the first four characters, underlined in the list of the option cards above, are required to be input. A brief description of each program option card follows.

ACCELERATION

This option enables the user to specify initial acceleration, at user-selected nodal points, for the direct time integration analysis. If this option is not specified, the initial accelerations are set to 0.

ANGULAR

This option defines a centrifugal distributed loading. The variables required for this option can be found in card group number 35.

BRICK

When this option is specified, a 8-node isoparametric 3D solid element will be used. This option card is to be used in conjunction with the S3DSOLID and the READ IN MODEL option cards. This element has 3 translational degrees of freedom identified by u_x, u_y, and u_z, as shown in Figure 3.11.

4th card in card group 42

1-4	I4	NPPLY1,1)	Initial ply for constituent properties and stresses of set 1.
5-8	I4	NPPLY(2,1)	Final ply for constituent properties and stresses of set 1.
9-12	I4	NPPLY(1,2)	Initial ply for constituent properties and stresses of set 2.
13-16	I4	NPPLY(2,2)	Final ply for constituent properties and stresses of set 2.
Etc.			Etc. in I4 format.

5th card in card group 42

1-10	F10.6	TIMEPN(1)	1st time at which a patran results file is written.
11-20	F10.6	TIMEPN(2)	2nd time at which a patran results file is written.
Etc.			Etc. in F10.6 format.

EXAMPLE:

Card Group 42

```
         1         2         3         4         5         6
1........0.........0.........0.........0.........0.........0
   1  81
   1   9  73  81
  41  41
   1   4
      10.0
```

Columns	Field Name	Value	Description
1-4	NPRT(1,1)	1	First node in the 1st series of nodal displacements is 1.
5-8	NPRT(2,1)	81	Last node in the 1st series of nodal displacements is 81.
1-4	NPRTS(1,1)	1	First node in the 1st series of nodal ply stress is 1.
5-8	NPRTS(2,1)	9	Last node in the 1st series of nodal ply stress is 9.
9-12	NPRTS(1,2)	73	First node in the 2nd series of nodal ply stress is 73.
13-16	NPRTS(2,2)	81	Last node in the 2nd series of nodal ply stress is 81.

BUCKLE

This option activates the buckling analysis. To determine the critical buckling load, MHOST uses the subspace iteration method. For a description of this method, see Reference 7. When this option is used, a buckling analysis is performed at the initial load and the times specified in the array TIMEMB.

DAMP

This option defines damping for the direct time integration analysis. At the present time, only Rayleigh damping is available in HITCAN. Thus damping matrix [C] is of the form

$$[C] = a[M] + \beta[K],$$

where a is the damping coefficient of the mass matrix [M] and ß is the damping coefficient of the stiffness matrix [K].

DISPLACEMENT

This option enables the user to specify initial displacements, at user-selected nodal points, for the direct time integration analysis. If this option is not specified, the initial displacements are set to 0.

DYNAMIC

This option activates the direct time integration dynamic analysis. The integration scheme used is the Newmark-Beta method. For a description of this method, see Reference 7.

ECHO

This option activates the print out of a reflection of the input data, prior to interpretation by HITCAN. No other cards are required to be input in conjunction with this option.

ENDOPTION

This option represents the end of the "Program Option Cards" block. It must be the last card in this block. No other cards are required to be input in conjunction with this option.

FE MODEL ONLY

This option enables the user to generate a finite element mesh of the structure without conducting any analysis. The mesh is output in a PATRAN neutral file format. No other cards are required to be input in conjunction with this option.

FORCE

This option allows the user to input static concentrated nodal loads.

HPLATE

This option activates the modeling of a hollow structure using the plate element. This option can only be used with the plate element, thus the program option card PLATE must also be specified.

INTERPHASE

This option enables the user to specify the existence of a discrete interphase between the fiber and the matrix. The thickness of the interphase is specified as a fraction of the fiber diameter.

MODAL

When this option is used HITCAN will perform a free vibration dynamic analysis to determine the frequencies and the mode shapes. To determine the frequencies and the mode shapes, MHOST uses the subspace iteration method. For a description of this method, see Reference 7.

PANEL

If this option is specified along with the HPLATE program option card a finite element model of a hollow panel can be generated. With this option the vertical members of the panel are evenly spaced. Note that the spars represent the sides of the panel. A typical panel is illustrated in Figure 3.7. No other cards are required to be input in conjunction with this option.

PLATE

This option selects the four-node isoparametic plate element both for the solid (SPLATE model option) and the hollow (HPLATE model option) structures. This element, which was derived from the Reissner-Mindlin theory for plates and shells, has 6 degrees-of-freedom at each node. These degrees-of-freedom are identified by u_x, u_y, u_z, H_x, H_y, and H_z. This element is shown in Figure 3.12.

PLYORDER

This option allows the user to build a composite model by defined plies over the surface of the structure and through the thickness producing an integrated laminated model of the entire structure. The user has the flexibility of selecting the number of plies, the ply thickness, the fiber volume ratio, the

void volume ratio, and the fiber orientation in building either a symmetric or an unsymmetric ply layup. When PLYORDER is used in conjunction with the program option card, UNSYMMETRICAL, the user can generate an unsymmetric ply layup. However, when the HPLATE model option is specified, only symmetric ply layups can be used.

PRESSURE

This option allows the user to input the pressure loading. For either solid or hollow structures using the plate element, the user can specify both a lateral pressure and an uniform edge pressure. For the plane stress, plane strain, and 3D solid elements only an uniform edge pressure can be specified. Note that if PL and PU are used to input the pressure loading the variables TL and TU must also be specified. If temperature effects are not desired, then TL and TU must be set to the reference temperature.

PROFILE

Without the presence of this card the nodal input points are assumed to be on the outer surface of the shell. HITCAN will then correct the grid point positions by moving them to the mid-wall poistion in a direction normal to the surface.

This option will suppress this mid-wall correction and will retain the grid points on the external profile of the shell. This option can be used only with the HPLATE model option.

READ IN MODEL

This option allows the user to input a finite element model using eight-node solid elements. The user must provide the element connectivities and the nodal coordinates. When this option is chosen, the user must also specify the BRICK program option card.

RESTART

This option enables the user to conduct an analysis in several runs, an useful option for large problems. When the RESTART option is specified, a restart file created in a previous run is input. This file contains the necessary information to continue the analysis, including, the load step number, increment number, ply stresses, microstresses, microstress rates, material failure flags, and nodal displacements. For a restart run, the input is the same as before, except that RESTART is now specified in the program option cards.

A restart file is created by specifying the variable MSTART. MSTART is the number of increments to be preformed in a particular run. After the analysis has progressed through MSTART increments, a restart file is created and the run is

terminated. Note that a restart file will also be created when the maximum number of allowable iterations (the variable MITER) in HITCAN is exceeded.

S3DSOLID

This option activates the modeling of a solid structure using the 3D solid element.

SPLATE

This option activates the modeling of a solid structure using the plate, plane stress, or plane strain elements.

STRAIN

This option specifies, that a four-node isoparametic plane strain element will be used in the analysis. Each node within this element has 2 degrees-of-freedom, identified by u_x and u_y. This element is shown in Figure 3.12.

STRESS

This option specifies, that a four-node isoparametic plane stress element will be used in the analysis. Each node within this element has 2 degrees-of-freedom, identified by u_x and u_y. This element is shown in Figure 3.13.

TEMPERATURE

This option allows the user to input a distributed temperature loading. Note that if TL and TU are used to input the temperature loading the variables PL and PU must also be specified. If there is no lateral pressure loading, then PL and PU should be set 0. The ply temperatures generated by TL and TU will be overridden by the ply temperatures contained in the variable TEPLY.

TITLE=

A maximum of 5 title lines are allowed. Each title line may have a maximum of 74 characters following the equal sign.

TRANSFORMATION

This option allows the user to specify a coordinate transformation of the global coordinate system into a local coordinate system at specified nodes. If more than one rotation is applied at a node, HITCAN executes all the entered rotations successively. This feature can be used to obtain transformations around an arbitrary axis. Each subsequent rotation acts upon the last previous coordinate system defined at the node. Note that this option follows the right hand coordinate system.

UNSYMMETRICAL PLYORDER

This option specifies an unsymmetric ply layup. This option is to be used in conjunction with the PLYORDER program option card.

VELOCITY

This option enables the user to specify initial velocities, at user-selected nodal points, for the direct time integration analysis. If this option is not specified, the initial velocities are set to 0.

3.9 DATABANK

As discussed previously, a HITCAN input file contains all of the necessary input to execute HITCAN, except for the thermal-mechanical properties of the composite material. These properties reside in a file labeled "Data Bank". The user may chose any other name for this file. The data bank file supplied with the code contains the properties for several aerospace composite materials. This file can be modified by the user for other materials using the input described below.

The organization of the data bank is shown in Figure 3.19. As can be seen in the figure, the first section of the data bank contains the fiber constituent properties, the second section contains the matrix constituent properties, and the third section contains the interphase properties. The data bank file separates the input for the different constituent materials (fiber, matrix, interphase) by a material identifier code as the first line of input for that material. This identifier is followed by the properties data, at the end of which, starts a new material identifier code. The material identifier codes for the fiber and the matrix consists of 4 unique characters. The interphase code consists of 9 characters. The first 4 of the 9 characters, are the code for the fiber type used in the interphase. The fiber type is then followed by a slash. The last 4 characters of the interphase code are the code for the matrix type used in the interphase. Note that the interphase code must be a combination of the same fiber and matrix codes that are used.

The format of variables used in the data bank is shown on the following pages.

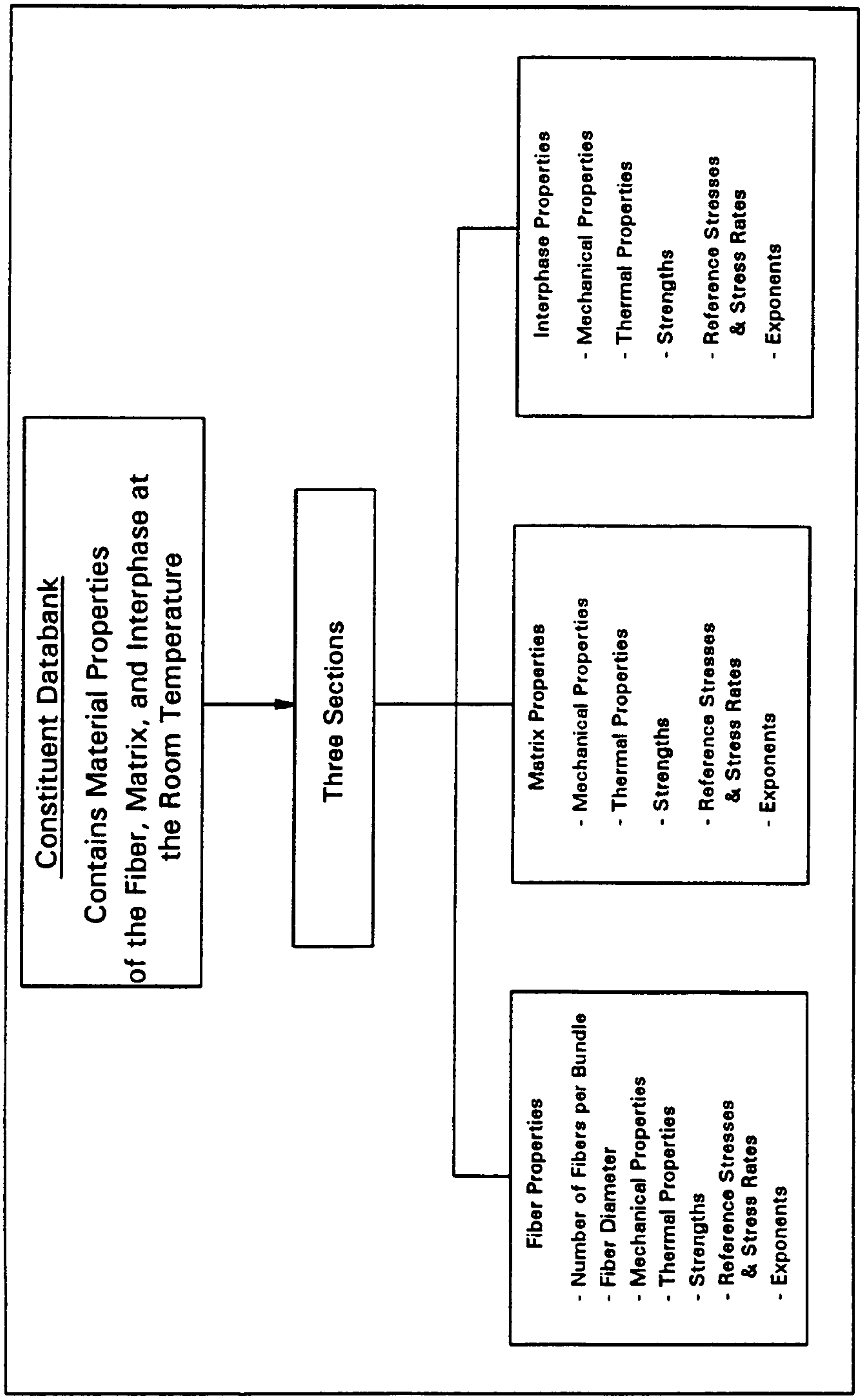

Figure 3.19: Organization of Constituent Databank

FIBER PROPERTIES

Columns	Format	Variable Name	Entry
1st card			
1-2	I2	NFTYP	Number of fiber data sets.

Cards 2 to 13 are repeated NFTYP times.

Columns	Format	Variable Name	Entry
2nd card			
1-4	A4	DUN1	Name of fiber.
3rd card			
1-6	I6	NDUN1	Number of fibers per bundle.
7-6	F10.3	DUN2	Fiber diameter in inches.
4th card			
1-5	I5	NUMFPO	Number of fiber properties.
6-10	I5	NUMFSO	Number of fiber microstresses.
11-15	I5	NUMFQO	Number of fiber microstress rates.
16-20	I5	NUMFT	Number fiber exponents.
5th card			
1-10	F10.3	TEMPF	Reference temperature in °F.
11-20	F10.3	TEMPMF	Melting temperature in °F.
21-30	F10.3	DOTHF	Limit-state value of stress rate in lb/in^2 sec.
31-40	F10.3	RHOF	Fiber density in lb/in^3.
41-50	F10.3	EF11	Modulus longitudinal in lb/in^2.
51-60	F10.3	EF22	Modulus transverse in lb/in^2.
61-70	F10.3	GF12	Shear modulus in lb/in^2.
71-80	F10.3	GF23	Shear modulus in lb/in^2.
6th card			
1-10	F10.3	NUF12	Poisson's ratio.
11-20	F10.3	NUF23	Poisson's ratio.
21-30	F10.3	CPF	Heat capacity in Btu/lb°F.
31-40	F10.3	KF11	Thermal conductivity longitudinal in Btu/hr-ft^2°F/in.
41-50	F10.3	KF22	Thermal conductivity transverse in Btu/hr-ft^2°F/in.

Columns	Format	Variable Name	Entry
51-60	F10.3	AF11	Thermal expansion coefficient longitudinal in in/in/°F.
61-70	F10.3	AF22	Thermal expansion coefficient transverse in in/in/°F.
71-80	F10.3	SF11t	Longitudinal strength - tension in lb/in^2.

7th card

Columns	Format	Variable Name	Entry
1-10	F10.3	SF11c	Longitudinal strength - compression in lb/in^2.
11-20	F10.3	SF22t	Transverse strength - tension in lb/in^2.
21-30	F10.3	SF22c	Transverse strength - compression in lb/in^2.
31-40	F10.3	SF12s	Shear strength in lb/in .
41-50	F10.3	SF23s	Shear strength in lb/in^2.

8th card

Columns	Format	Variable Name	Entry
1-10	F10.3	RF11	Reference longitudinal stress in lb/in^2.
11-20	F10.3	RF22	Reference transverse stress in lb/in^2.
21-30	F10.3	RF12	Reference shear stress in lb/in^2.
31-40	F10.3	RF23	Reference shear stress in lb/in^2.
41-50	F10.3	RF13	Reference shear stress in lb/in^2.

9th card

Columns	Format	Variable Name	Entry
1-10	F10.3	QF11	Reference longitudinal stress rate in $lb/in^2 sec$.
11-20	F10.3	QF22	Reference transverse stress rate in $lb/in^2 sec$.
21-30	F10.3	QF12	Reference shear stress rate in $lb/in^2 sec$.
31-40	F10.3	QF23	Reference shear stress rate in $lb/in^2 sec$.
41-50	F10.3	QF13	Reference shear stress rate in $lb/in^2 sec$.

10th card

Columns	Format	Variable Name	Entry
1-10	F10.3	FTVCI(1)	Modulus - exponent on stress rate.
11-20	F10.3	FTVCI(2)	Modulus - exponent on stress.
21-30	F10.3	FTVCI(3)	Modulus - exponent on temperature.
31-40	F10.3	FTVCI(4)	Strength - exponent on stress rate.
41-50	F10.3	FTVCI(5)	Strength - exponent on stress.

Columns	Format	Variable Name	Entry
51-60	F10.3	FTVCI(6)	Strength - exponent on temperature.
61-70	F10.3	FTVCI(7)	Poisson's ratio - exponent on stress rate.
71-80	F10.3	FTVCI(8)	Poisson's ratio - exponent on stress.
11th card			
1-10	F10.3	FTVCI(9)	Poisson's ratio - exponent on temperature.
11-20	F10.3	FTVCI(10)	Not used.
21-30	F10.3	FTVCI(11)	Not used.
31-40	F10.3	FTVCI(12)	Not used.
41-50	F10.3	FTVCI(13)	Heat conductivity - exponent on stress rate.
51-60	F10.3	FTVCI(14)	Heat conductivity - exponent on stress.
61-70	F10.3	FTVCI(15)	Heat conductivity - exponent on temperature.
71-80	F10.3	FTVCI(16)	Thermal expansion coefficient - exponent on stress rate.
12th card			
1-10	F10.3	FTVCI(17)	Thermal expansion coefficient - exponent on stress.
11-20	F10.3	FTVCI(18)	Thermal expansion coefficient - exponent on temperature.
21-30	F10.3	FTVCI(19)	Not used.
31-40	F10.3	FTVCI(20)	Not used.
Etc.			Etc. in F10.3 format
13th card			
1-10	F10.3	FTVCI(25)	Not used.
11-20	F10.3	FTVCI(26)	Not used.
Etc.			Etc. in F10.3 format

EXAMPLE: Silicon Carbide on Aluminum

Card Group 19

```
         1         2         3         4         5         6         7
1........0.........0.........0.........0.........0.........0.........0.........
    1
SICA
     1    .0056
   21    5    5   30
70.       4870.     1000000.  .11       62000000. 62000000. 23800000. 23800000.
0.3       .3        .29       .75       .75       .0000018  .0000018  500000.
650000.   500000.   650000.   300000.   300000.
.0        .0        .0        .0        .0
.0        .0        .0        .0        .0
.25       .25       .25       .0        .0        .25       .25       .25
.25                                     .25       .25       .25       .25
.25       .25
```

Columns	Field Name	Value	Description
1-2	NFTYP	1	1 fiber data set.
1-4	DUN1	SICA	The fiber material identification code is SICA.
1-6	NDUN1	1	Number of fibers per bundle is 1.
7-16	DUN2	.0056	The fiber diameter is .0056 inches.
1-5	NUMFPO	21	There are 21 fiber properties.
6-10	NUMFSO	5	The number of reference fiber microstresses is 5.
11-15	NUMFQO	5	The number of reference fiber microstress rates is 5.
16-20	NUMFT	30	The number of exponents is 30.
1-10	TEMPF	70	The reference temperature is 70 °F.
11-20	TEMPMF	4870	The melting temperature is 4870 °F.
21-30	DOTHF	1000000	The limit-state value of stress rate is 1000000. lb/in^2sec.
31-40	RHOF	.11	Fiber density is .11 lb/in^3.
41-50	EF11	62000000	The longitudinal modulus is 62000000 lb/in^2.
51-60	EF22	62000000	The transverse modulus is 62000000 lb/in^2.
61-70	GF12	23800000	The shear modulus is 23800000 lb/in^2.
71-80	GF23	23800000	The shear modulus is 23800000 lb/in^2.
1-10	NUF12	.3	Poisson's ratio is .3.
11-20	NUF23	.3	Poisson's ratio is .3.
21-30	CPF	.29	Heat capacity is .29 Btu/lb°F.

Columns	Field Name	Value	Description
31-40	KF11	.75	Thermal conductivity longitudinal is .75 Btu/hr-ft^{2o}F/in.
41-50	KF22	.75	Thermal conductivity transverse is .75 Btu/hr-ft^{2o}F/in.
51-60	AF11	.0000018	Thermal expansion coefficient longitudinal is .0000018 in/in/°F.
61-70	AF22	.0000018	Thermal expansion coefficient transverse is.0000018 in/in/°F.
71-80	SF11t	500000	Longitudinal strength - tension is 500000 lb/in^2.
1-10	SF11c	650000	Longitudinal strength - compression is 650000 lb/in^2.
11-20	SF22t	500000	Transverse strength - tension is 500000 lb/in^2.
21-30	SF22c	650000	Transverse strength - compression is 650000 lb/in^2.
31-40	SF12s	300000	Shear strength is 300000 lb/in .
41-50	SF23s	300000	Shear strength is 300000 lb/in^2.
1-10	RF11	.0	Reference longitudinal stress is .0 lb/in^2.
11-20	RF22	.0	Reference transverse stress is .0 lb/in^2.
21-30	RF12	.0	Reference shear stress is .0 lb/in^2.
31-40	RF23	.0	Reference shear stress is .0 lb/in^2.
41-50	RF13	.0	Reference shear stress is .0 lb/in^2.
1-10	QF11	.0	Reference longitudinal stress rate is .0 lb/in^{2}sec.
11-20	QF22	.0	Reference transverse stress rate is .0 lb/in^{2}sec.
21-30	QF12	.0	Reference shear stress rate is .0 lb/in^{2}sec.
31-40	QF23	.0	Reference shear stress rate is .0 lb/in^{2}sec.
41-50	QF13	.0	Reference shear stress rate is .0 lb/in^{2}sec.
1-10	FTVCI(1)	.25	Modulus - exponent on stress rate is .25.
11-20	FTVCI(2)	.25	Modulus - exponent on stress is .25.
21-30	FTVCI(3)	.25	Modulus - exponent on temperature is .25.
31-40	FTVCI(4)	.0	Strength - exponent on stress rate is .0.
41-50	FTVCI(5)	.0	Strength - exponent on stress is .0.
51-60	FTVCI(6)	.25	Strength - exponent on temperature is .25.
61-70	FTVCI(7)	.25	Poisson's ratio - exponent on stress rate is .25.

71-80	FTVCI(8)	.25	Poisson's ratio - exponent on stress is .25.
1-10	FTVCI(9)	.25	Poisson's ratio - exponent on temperature is .25.
11-20	FTVCI(10)	Blank	
21-30	FTVCI(11)	Blank	
31-40	FTVCI(12)	Blank	
41-50	FTVCI(13)	.25	Heat conductivity - exponent on stress rate is .25.
51-60	FTVCI(14)	.25	Heat conductivity - exponent on stress is .25.
61-70	FTVCI(15)	.25	Heat conductivity - exponent on stress temperature is .25.
71-80	FTVCI(16)	.25	Thermal expansion coefficient - exponent on stress rate is .25.
1-10	FTVCI(17)	.25	Thermal expansion coefficient - exponent on stress is .25.
11-20	FTVCI(18)	.25	Thermal expansion coefficient - exponent on temperature is .25.
21-30	FTVCI(19)	Blank	
31-40	FTVCI(20)	Blank	
41-50	FTVCI(21)	Blank	
51-60	FTVCI(22)	Blank	
61-70	FTVCI(23)	Blank	
71-80	FTVCI(24)	Blank	
1-10	FTVCI(25)	Blank	
11-20	FTVCI(26)	Blank	
21-30	FTVCI(27)	Blank	
31-40	FTVCI(28)	Blank	
41-50	FTVCI(29)	Blank	
51-60	FTVCI(30)	Blank	

MATRIX PROPERTIES

Columns	Format	Variable Name	Entry
1st card			
1-2	I2	NMTYP	Number of matrix data sets.

Cards 2 to 14 are repeated NMTYP times.

Columns	Format	Variable Name	Entry
2nd card			
1-4	A4	DUN1	Name of matrix material.
3rd card			
1-5	I5	NUMMPO	Number of matrix properties.
6-10	I5	NUMMSO	Number of matrix microstresses.
11-15	I5	NUMMQO	Number of matrix microstress rates.
16-20	I5	NUMMT	Number of matrix exponents.
4th card			
1-10	F10.3	TEMPM	Reference temperature in °F.
11-20	F10.3	TEMPMM	Melting temperature in °F.
21-30	F10.3	DOTHM	Limit-state value of stress rate in lb/in^2sec.
31-40	F10.3	RHOM	Matrix density in lb/in^3.
41-50	F10.3	EM11	Modulus longitudinal in lb/in^2.
51-60	F10.3	EM22	Modulus transverse in lb/in^2.
61-70	F10.3	GM12	Shear modulus in lb/in^2.
71-80	F10.3	GM23	Shear modulus in lb/in^2.
5th card			
1-10	F10.3	NUM12	Poisson's ratio.
11-20	F10.3	NUM23	Poisson's ratio.
21-30	F10.3	CPM	Heat capacity in Btu/lb°F.
31-40	F10.3	KM11	Thermal conductivity longitudinal in $Btu/hr\text{-}ft^{2o}F/in$.
41-50	F10.3	KM22	Thermal conductivity transverse in $Btu/hr\text{-}ft^{2o}F/in$.
51-60	F10.3	AM11	Thermal expansion coefficient longitudinal in in/in/°F.
61-70	F10.3	AM22	Thermal expansion coefficient transverse in in/in/°F.
71-80	F10.3	SM11t	Longitudinal strength - tension in lb/in^2.

Columns	Format	Variable Name	Entry
6th card			
1-10	F10.3	SM11c	Longitudinal strength - compression in lb/in^2.
11-20	F10.3	SM22t	Transverse strength - tension in lb/in^2.
11-30	F10.3	SM22c	Transverse strength - compression in lb/in^2.
31-40	F10.3	SM12s	Shear strength in lb/in .
41-50	F10.3	SM23s	Shear strength in lb/in^2.
7th card			
1-10	F10.3	RM11	Reference longitudinal stress in lb/in^2.
11-20	F10.3	RM22a	Reference transverse stress - region a in lb/in^2.
21-30	F10.3	RM22b	Reference transverse stress - region b lb/in^2.
31-40	F10.3	RM22c	Reference transverse stress - region c in lb/in^2.
41-50	F10.3	RM12a	Reference shear stress - region a in lb/in^2.
51-60	F10.3	RM12b	Reference shear stress - region b in lb/in^2.
61-70	F10.3	RM12c	Reference shear stress - region c in lb/in^2.
71-80	F10.3	RM23a	Reference shear stress - region a in lb/in^2.
8th card			
1-10	F10.3	RM23b	Reference shear stress - region b in lb/in^2.
11-20	F10.3	RM23c	Reference shear stress - region c in lb/in^2.
21-30	F10.3	RM13a	Reference shear stress - region a in lb/in^2.
31-40	F10.3	RM13b	Reference shear stress - region b in lb/in^2.
41-50	F10.3	RM13c	Reference shear stress - region c in lb/in^2.
9th card			
1-10	F10.3	QM11	Reference longitudinal stress rate lb/in^2sec.

Columns	Format	Variable Name	Entry
11-20	F10.3	QM22a	Reference transverse stress rate - region a in lb/in^2sec.
21-30	F10.3	QM22b	Reference transverse stress rate - region b in lb/in^2sec.
31-40	F10.3	QM22c	Reference transverse stress rate - region c in lb/in^2sec.
41-50	F10.3	QM12a	Reference shear stress rate - region a in lb/in^2sec.
51-60	F10.3	QM12b	Reference shear stress rate - region b in lb/in^2sec.
61-70	F10.3	QM12c	Reference shear stress rate - region c in lb/in^2sec.
71-80	F10.3	QM23a	Reference shear stress rate - region a in lb/in^2sec.
10th card			
1-10	F10.3	QM23b	Reference shear stress rate - region b in lb/in^2sec.
11-20	F10.3	QM23c	Reference shear stress rate - region c in lb/in^2sec.
21-30	F10.3	QM13a	Reference shear stress rate - region a in lb/in^2sec.
1-40	F10.3	QM13b	Reference shear stress rate - region b in lb/in^2sec.
41-50	F10.3	QM13c	Reference shear stress rate - region c in lb/in^2sec.
11th card			
1-10	F10.3	MTVCI(1)	Modulus - exponent on stress rate.
11-20	F10.3	MTVCI(2)	Modulus - exponent on stress.
21-30	F10.3	MTVCI(3)	Modulus - exponent on temperature.
31-40	F10.3	MTVCI(4)	Strength - exponent on stress rate.
41-50	F10.3	MTVCI(5)	Strength - exponent on stress.
51-60	F10.3	MTVCI(6)	Strength - exponent on temperature.
61-70	F10.3	MTVCI(7)	Poisson's ratio - exponent on stress rate.
71-80	F10.3	MTVCI(8)	Poisson's ratio - exponent on stress.
12th card			
1-10	F10.3	MTVCI(9)	Poisson's ratio - exponent on temperature.
11-20	F10.3	MTVCI(10)	Not used.
21-30	F10.3	MTVCI(11)	Not used.
31-40	F10.3	MTVCI(12)	Not used.
41-50	F10.3	MTVCI(13)	Heat conductivity - exponent on stress rate.

Columns	Format	Variable Name	Entry
51-60	F10.3	MTVCI(14)	Heat conductivity - exponent on stress.
61-70	F10.3	MTVCI(15)	Heat conductivity - exponent on temperature.
71-80	F10.3	MTVCI(16)	Thermal expansion coefficient - exponent on stress rate.

13th card

Columns	Format	Variable Name	Entry
1-10	F10.3	MTVCI(17)	Thermal expansion coefficient - exponent on stress.
11-20	F10.3	MTVCI(18)	Thermal expansion coefficient - exponent on temperature.
21-30	F10.3	MTVCI(19)	Not used.
31-40	F10.3	MTVCI(20)	Not used.
Etc.			Etc. in F10.3 format

14th card

Columns	Format	Variable Name	Entry
1-10	F10.3	MTVCI(25)	Not used.
11-20	F10.3	MTVCI(26)	Not used.
Etc.			Etc. in F10.3 format

EXAMPLE: Titanium Aluminum

```
         1         2         3         4         5         6         7
1........0.........0.........0.........0.........0.........0.........0.........
 1
TI15
   21    13   13    30
70.       1800.     1000000.  .172      12300000. 12300000. 4659091.  4659091.
.32       .32       .12       .39       .39       .0000045  .0000045  130000.
130000.   130000.   130000.   91000.    91000.
.0        .0        .0        .0        .0        .0        .0        .0
.0        .0        .0        .0        .0
.0        .0        .0        .0        .0        .0        .0        .0
.0        .0        .0        .0        .0
.25       .25       .25       .0        .0        .25       .25       .25
.25                                     .25       .25       .25       .25
.25       .25
```

Columns	Field Name	Value	Description
1-2	NMTYP	1	1 matrix data set.
1-4	DUN1	TI15	The matrix material identification code is TI15.
1-5	NUMMPO	21	There are 21 matrix properties.
6-10	NUMMSO	5	The number of reference matrix microstresses is 5.
11-15	NUMMQO	5	The number of reference matrix microstress rates is 5.
16-20	NUMMT	30	The number of exponents is 30.
1-10	TEMPM	70	The reference temperature is 70 °F.
11-20	TEMPMM	1800	The melting temperature is 1800 °F.
21-30	DOTHM	1000000	The limit-state value of stress rate is 1000000. $lb/in^2 sec$.
31-40	RHOM	.172	Matrix density is .172 lb/in^3.
41-50	EM11	12300000	The longitudinal modulus is 12300000 lb/in^2.
51-60	EM22	12300000	The transverse modulus is 12300000 lb/in^2.
61-70	GM12	45659091	The shear modulus is 4659091 lb/in^2.
71-80	GM23	4659091	The shear modulus is 4659091 lb/in^2.
1-10	NUM12	.32	Poisson's ratio is .32.
11-20	NUM23	.32	Poisson's ratio is .32.
21-30	CPM	.29	Heat capacity is .12 Btu/lb°F.
31-40	KM11	.75	Thermal conductivity longitudinal is .39 $Btu/hr\text{-}ft^2 {}^\circ F/in$.
41-50	KM22	.75	Thermal conductivity transverse is .39 $Btu/hr\text{-}ft^2 {}^\circ F/in$.
51-60	AM11	.0000045	Thermal expansion coefficient longitudinal is .0000045 in/in/°F.
61-70	AM22	.0000045	Thermal expansion coefficient transverse is.0000045 in/in/°F.
71-80	SM11t	130000	Longitudinal strength - tension is 130000 lb/in^2.
1-10	SM11c	130000	Longitudinal strength - compression is 130000 lb/in^2.
11-20	SM22t	130000	Transverse strength - tension is 130000 lb/in^2.
21-30	SM22c	130000	Transverse strength - compression is 130000 lb/in^2.
31-40	SM12s	91000	Shear strength is 91000 lb/in .
41-50	SM23s	91000	Shear strength is 91000 lb/in^2.
1-10	RM11	.0	Reference longitudinal stress is .0 lb/in^2.
11-20	RM22a	.0	Reference transverse stress - region a is .0 lb/in^2.
21-30	RM22b	.0	Reference transverse stress - region b is .0 lb/in^2.

Columns	Field Name	Value	Description
31-40	RM22c	.0	Reference transverse stress - region c is .0 lb/in^2.
41-50	RM12a	.0	Reference shear stress - region a is .0 lb/in^2.
51-60	RM12b	.0	Reference shear stress - region b is .0 lb/in^2.
61-70	RM12c	.0	Reference shear stress - region c is .0 lb/in^2.
71-80	RM23a	.0	Reference shear stress - region a is .0 lb/in^2.
1-10	RM23b	.0	Reference shear stress - region b is .0 lb/in^2.
11-20	RM23c	.0	Reference shear stress - region c is .0 lb/in^2.
21-30	RM13a	.0	Reference shear stress - region a is .0 lb/in^2.
31-40	RM13b	.0	Reference shear stress - region b is .0 lb/in^2.
41-50	RM13c	.0	Reference shear stress - region c is .0 lb/in^2.
1-10	QM11	.0	Reference longitudinal stress rate is .0 lb/in^2sec.
11-20	QM22a	.0	Reference transverse stress rate - region a is .0 lb/in^2sec.
21-30	QM22b	.0	Reference transverse stress rate - region b is .0 lb/in^2sec.
31-40	QM22c	.0	Reference transverse stress rate - region c is .0 lb/in^2sec.
1-50	QM12a	.0	Reference shear stress rate - region a is .0 lb/in^2sec.
51-60	QM12b	.0	Reference shear stress rate - region b is .0 lb/in^2sec.
61-70	QM12c	.0	Reference shear stress rate - region c is .0 lb/in^2sec.
71-80	QM23a	.0	Reference shear stress rate - region a is .0 lb/in^2sec.
1-10	QM23b	.0	Reference shear stress rate - region b is .0 lb/in^2sec.
11-20	QM23c	.0	Reference shear stress rate - region c is .0 lb/in^2sec.
21-30	QM13a	.0	Reference shear stress rate - region a is .0 lb/in^2sec.
31-40	QM13b	.0	Reference shear stress rate - region b is .0 lb/in^2sec.
41-50	QM13c	.0	Reference shear stress rate - region c is .0 lb/in^2sec.
1-10	MTVCI(1)	.25	Modulus - exponent on stress rate is .25.

Columns	Field Name	Value	Description
11-20	MTVCI(2)	.25	Modulus - exponent on stress is .25.
21-30	MTVCI(3)	.25	Modulus - exponent on temperature is .25.
31-40	MTVCI(4)	.0	Strength - exponent on stress rate is .0.
41-50	MTVCI(5)	.0	Strength - exponent on stress is .0.
51-60	MTVCI(6)	.25	Strength - exponent on temperature is .25.
61-70	MTVCI(7)	.25	Poisson's ratio - exponent on stress rate is .25.
71-80	MTVCI(8)	.25	Poisson's ratio - exponent on stress is .25.
1-10	MTVCI(9)	.25	Poisson's ratio - exponent on temperature is .25.
11-20	MTVCI(10)	Blank	
21-30	MTVCI(11)	Blank	
31-40	MTVCI(12)	Blank	
41-50	MTVCI(13)	.25	Heat conductivity - exponent on stress rate is .25.
51-60	MTVCI(14)	.25	Heat conductivity - exponent on stress is .25.
61-70	MTVCI(15)	.25	Heat conductivity - exponent on temperature is .25.
71-80	MTVCI(16)	.25	Thermal expansion coefficient - exponent on stress rate is .25.
1-10	MTVCI(17)	.25	Thermal expansion coefficient - exponent on stress is .25.
11-20	MTVCI(18)	.25	Thermal expansion coefficient - exponent on temperature is .25.
21-30	MTVCI(19)	Blank	
31-40	MTVCI(20)	Blank	
41-50	MTVCI(21)	Blank	
51-60	MTVCI(22)	Blank	
61-70	MTVCI(23)	Blank	
71-80	MTVCI(24)	Blank	
1-10	MTVCI(25)	Blank	
11-20	MTVCI(26)	Blank	
21-30	MTVCI(27)	Blank	
31-40	MTVCI(28)	Blank	
41-50	MTVCI(29)	Blank	
51-60	MTVCI(30)	Blank	

INTERPHASE PROPERTIES

Columns	Format	Variable Name	Entry
1st card			
1-2	I2	NDTYP	Number of interphase data sets.

Cards 2 to 15 are repeated NDTYP times.

Columns	Format	Variable Name	Entry
2nd card			
1-4	A4	DUN1	Name of fiber.
5	1X		
6-9	A4	DUN2	Name of matrix.
3rd card			
1-5	I5	NUMDPO	Number of interphase properties.
6-10	I5	NUMDSO	Number of interphase microstresses.
11-15	I5	NUMDQO	Number of interphase microstress rates.
16-20	I5	NUMDT	Number of interphase exponents.
4th card			
1-10	F10.3	TEMPD	Reference temperature in °F.
11-20	F10.3	TEMPMD	Melting temperature in °F.
21-30	F10.3	DOTHD	Limit-state value of stress rate in lb/in^2sec.
31-40	F10.3	RHOD	Interphase density in lb/in^3.
41-50	F10.3	ED11	Modulus longitudinal in lb/in^2.
51-60	F10.3	ED22	Modulus transverse in lb/in^2.
61-70	F10.3	GD12	Shear modulus in lb/in^2.
71-80	F10.3	GD23	Shear modulus in lb/in^2.
5th card			
1-10	F10.3	NUD12	Poisson's ratio.
11-20	F10.3	NUD23	Poisson's ratio.
21-30	F10.3	CPD	Heat capacity in Btu/lb°F.
31-40	F10.3	KD11	Thermal conductivity longitudinal in $Btu/hr\text{-}ft^{2o}F/in$.
41-50	F10.3	KD22	Thermal conductivity transverse in $Btu/hr\text{-}ft^{2o}F/in$.
51-60	F10.3	AD11	Thermal expansion coefficient longitudinal in in/in/°F.
61-70	F10.3	AD22	Thermal expansion coefficient transverse

Columns	Format	Variable Name	Entry
			in in/in/°F.
71-80	F10.3	SD11t	Longitudinal strength - tension in lb/in^2.
6th card			
1-10	F10.3	SD11c	Longitudinal strength - compression in lb/in^2.
11-20	F10.3	SD22t	Transverse strength - tension in lb/in^2.
21-30	F10.3	SD22c	Transverse strength - compression in lb/in^2.
31-40	F10.3	SD12s	Shear strength in lb/in .
41-50	F10.3	SD23s	Shear strength in lb/in^2.
7th card			
1-10	F10.3	RD11	Reference longitudinal stress in lb/in^2.
11-20	F10.3	RD22b	Reference transverse stress - region b lb/in^2.
21-30	F10.3	RD22c	Reference transverse stress - region c in lb/in^2.
31-40	F10.3	RD12b	Reference shear stress - region b in lb/in^2.
41-50	F10.3	RD12c	Reference shear stress - region c in lb/in^2.
51-60	F10.3	RD23b	Reference shear stress - region b in lb/in^2.
61-70	F10.3	RD23c	Reference shear stress - region c in lb/in^2.
71-80	F10.3	RD13b	Reference shear stress - region b in lb/in^2.
8th card			
1-10	F10.3	RD13c	Reference shear stress - region c in lb/in^2.
9th card			
1-10	F10.3	QD11	Reference longitudinal stress rate lb/in^2sec.
11-20	F10.3	QD22b	Reference transverse stress rate - region b in lb/in^2sec.
21-30	F10.3	QD22c	Reference transverse stress rate - region c in lb/in^2sec.
31-40	F10.3	QD12b	Reference shear stress rate - region b in lb/in^2sec.

Columns	Format	Variable Name	Entry
41-50	F10.3	QD12c	Reference shear stress rate - region c in lb/in^2sec.
51-60	F10.3	QD23b	Reference shear stress rate - region b in lb/in^2sec.
61-70	F10.3	QD23c	Reference shear stress rate - region c in lb/in^2sec.
71-80	F10.3	QM13b	Reference shear stress rate - region b in lb/in^2sec.

10th card

Columns	Format	Variable Name	Entry
1-10	F10.3	QD13c	Reference shear stress rate - region c in lb/in^2sec.

11th card

Columns	Format	Variable Name	Entry
1-10	F10.3	DTVCI(1)	Modulus - exponent on stress rate.
11-20	F10.3	DTVCI(2)	Modulus - exponent on stress.
21-30	F10.3	DTVCI(3)	Modulus - exponent on temperature.
31-40	F10.3	DTVCI(4)	Strength - exponent on stress rate.
41-50	F10.3	DTVCI(5)	Strength - exponent on stress.
51-60	F10.3	DTVCI(6)	Strength - exponent on temperature.
61-70	F10.3	DTVCI(7)	Poisson's ratio - exponent on stress rate.
71-80	F10.3	DTVCI(8)	Poisson's ratio - exponent on stress.

12th card

Columns	Format	Variable Name	Entry
1-10	F10.3	DTVCI(9)	Poisson's ratio - exponent on temperature.
11-20	F10.3	DTVCI(10)	Not used.
21-30	F10.3	DTVCI(11)	Not used.
31-40	F10.3	DTVCI(12)	Not used.
41-50	F10.3	DTVCI(13)	Heat conductivity - exponent on stress rate.
51-60	F10.3	DTVCI(14)	Heat conductivity - exponent on stress.
61-70	F10.3	DTVCI(15)	Heat conductivity - exponent on temperature.
71-80	F10.3	DTVCI(16)	Thermal expansion coefficient - exponent on stress rate.

13th card

Columns	Format	Variable Name	Entry
1-10	F10.3	DTVCI(17)	Thermal expansion coefficient - exponent on stress.
11-20	F10.3	DTVCI(18)	Thermal expansion coefficient - exponent on temperature.
21-30	F10.3	DTVCI(19)	Not used.
31-40	F10.3	DTVCI(20)	Not used.
Etc.			Etc. in F10.3 format

Columns	Format	Variable Name	Entry
14th card			
1-10	F10.3	DTVCI(25)	Not used.
11-20	F10.3	DTVCI(26)	Not used.
Etc.			Etc. in F10.3 format
15th card			
1-10	F10.3	TREF	Reference temperature in °F.

EXAMPLE: SICA/TI15 Interphase

```
         1         2         3         4         5         6         7
1........0.........0.........0.........0.........0.........0.........0.........
 1
SICA/TI15
   21    9    9   30
70.       3335.     1000000.  .141      37150000. 37150000.14229546. 14229546.
.31       .31       .205      .57       .57       .0000032  .0000032  315000.
390000.   315000.   390000.   195500.   195500.
.0        .0        .0        .0        .0        .0        .0        .0
.0
.0        .0        .0        .0        .0        .0        .0        .0
.0
.5        .5        .5        .0        .0        .5        .5        .5
.5                                      .5        .5        .5        .5
.5        .5
70.
```

Columns	Field Name	Value	Description
1-2	NDTYP	1	1 interphase data set.
1-4	DUN1	SICA	The fiber material identification code is SICA.
6-9	DUN2	TI15	The matrix material identification code is TI15.
1-5	NUMDPO	21	There are 21 interphase properties.
6-10	NUMDSO	5	The number of reference interphase microstresses is 5.
11-15	NUMDQ0	5	The number of reference interphase microstress rates is 5.
16-20	NUMDT	30	The number of exponents is 30.
1-10	TEMPD	70	The reference temperature is 70 °F.
11-20	TEMPMD	3335	The melting temperature is 3335 °F.
21-30	DOTHD	1000000	The limit-state value of stress rate is 1000000. lb/in^2sec.

Columns	Field Name	Value	Description
31-40	RHOD	.141	Interphase density is .172 lb/in^3.
41-50	ED11	37150000	The longitudinal modulus is 37150000 lb/in^2.
51-60	ED22	37150000	The transverse modulus is 37150000 lb/in^2.
61-70	GD12	14229546	The shear modulus is 14229546 lb/in^2.
71-80	GD23	14229546	The shear modulus is 14229546 lb/in^2.
1-10	NUD12	.31	Poisson's ratio is .31.
11-20	NUD23	.31	Poisson's ratio is .31.
21-30	CPD	.205	Heat capacity is .205 Btu/lb°F.
31-40	KD11	.57	Thermal conductivity longitudinal is .57 Btu/hr-ft^2°F/in.
41-50	KD22	.57	Thermal conductivity transverse is .57 Btu/hr-ft^2°F/in.
51-60	AD11	.0000032	Thermal expansion coefficient longitudinal is .0000032 in/in/°F.
61-70	AD22	.0000032	Thermal expansion coefficient transverse is.0000032 in/in/°F.
71-80	SD11t	315000	Longitudinal strength - tension is 315000 lb/in^2.
1-10	SD11c	390000	Longitudinal strength - compression is 390000 lb/in^2.
11-20	SD22t	315000	Transverse strength - tension is 315000 lb/in^2.
21-30	SD22c	390000	Transverse strength - compression is 390000 lb/in^2.
31-40	SD12s	195500	Shear strength is 195500 lb/in .
41-50	SD23s	195500	Shear strength is 195500 lb/in^2.
1-10	RD11	.0	Reference longitudinal stress is .0 lb/in^2.
11-20	RD22b	.0	Reference transverse stress - region b is .0 lb/in^2.
21-30	RD22c	.0	Reference transverse stress - region c is .0 lb/in^2.
31-40	RD12b	.0	Reference shear stress - region b is .0 lb/in^2.
41-50	RD12c	.0	Reference shear stress - region c is .0 lb/in^2.
51-60	RD23b	.0	Reference shear stress - region b is .0 lb/in^2.
61-70	RD23c	.0	Reference shear stress - region c is .0 lb/in^2.
71-80	RD13b	.0	Reference shear stress - region b is .0 lb/in^2.
1-10	RD13c	.0	Reference shear stress - region c is .0 lb/in^2.
1-10	QD11	.0	Reference longitudinal stress rate is .0 lb/in^2sec.

Columns	Field Name	Value	Description
11-20	QD22b	.0	Reference transverse stress rate - region b is .0 lb/in^2sec.
21-30	QD22c	.0	Reference transverse stress rate - region c is .0 lb/in^2sec.
31-40	QD12b	.0	Reference shear stress rate - region b is .0 lb/in^2sec.
41-50	QD12c	.0	Reference shear stress rate - region c is .0 lb/in^2sec.
51-60	QD23b	.0	Reference shear stress rate - region b is .0 lb/in^2sec.
61-70	QD23c	.0	Reference shear stress rate - region c is .0 lb/in^2sec.
71-80	QD13b	.0	Reference shear stress rate - region b is .0 lb/in^2sec.
1-10	QD13c	.0	Reference shear stress rate - region c is .0 lb/in^2sec.
1-10	DTVCI(1)	.5	Modulus - exponent on stress rate is .5.
11-20	DTVCI(2)	.5	Modulus - exponent on stress is .5.
21-30	DTVCI(3)	.5	Modulus - exponent on temperature is .5.
31-40	DTVCI(4)	.0	Strength - exponent on stress rate is .0.
41-50	DTVCI(5)	.0	Strength - exponent on stress is .0.
51-60	DTVCI(6)	.5	Strength - exponent on tempeature is .5.
61-70	DTVCI(7)	.5	Poisson's ratio - exponent on stress rate is .5.
71-80	DTVCI(8)	.5	Poisson's ratio - exponent on stress rate is .5.
1-10	DTVCI(9)	.5	Poisson's ratio - exponent on temperature is .5.
11-20	DTVCI(10)	Blank	
21-30	DTVCI(11)	Blank	
31-40	DTVCI(12)	Blank	
41-50	DTVCI(13)	.5	Heat conductivity - exponent on stress rate is .5.
51-60	DTVCI(14)	.5	Heat conductivity - exponent on stress is .5.
61-70	DTVCI(15)	.5	Heat conductivity - exponent on temperature is .5.
71-80	DTVCI(16)	.5	Thermal expansion coefficient - exponent on stress rate is .5.
1-10	DTVCI(17)	.5	Thermal expansion coefficient - exponent on stress is .5.
11-20	DTVCI(18)	.5	Thermal expansion coefficient - exponent on temperature is .5.
21-30	DTVCI(19)	Blank	

Columns	Field Name	Value	Description
31-40	DTVCI(20)	Blank	
41-50	DTVCI(21)	Blank	
51-60	DTVCI(22)	Blank	
61-70	DTVCI(23)	Blank	
71-80	DTVCI(24)	Blank	
1-10	DTVCI(25)	Blank	
11-20	DTVCI(26)	Blank	
21-30	DTVCI(27)	Blank	
31-40	DTVCI(28)	Blank	
41-50	DTVCI(29)	Blank	
51-60	DTVCI(30)	Blank	
1-10	TREF	70.	Reference temperature is 70 °F.

CHAPTER 4

EXECUTION PROCEDURE ON THE LeRC CRAY X-MP AND Y-MP

HITCAN is presently being executed in the batch mode on the CRAY X-MP and the CRAY Y-MP here at the NASA LeRC. Figure 4.1 shows both the input and output files for HITCAN. The primary input file is input.data. The file data.bank contains the data bank. restart.in is the restart file. This file is only read in if the program option card RESTART is specified. The file restart.out is the restart file that is created by HITCAN. This file is generated by HITCAN when there is a lack of global convergence or when the variable MSTART is used. pat.neut is a PATRAN neutral file. This file contains the necessary data to view the finite element model using PATRAN. The file pat.disp contains the nodal displacements. This file can be used for post-processing on PATRAN.

To compile and load HITCAN on the CRAY X-MP, the following nqs script can be used:

```
# USER=userid PW=userpwd
# QSUB-r      jobid
# QSUB-lT     cputime
# QSUB -lM    memory
# QSUB-eo
set -x
cft -d p /aerospace2/userid/hitcan.f
segldr -o /aerospace2/userid/hitcan hitcan.o
exit
```

The variable userid is the user's id on the CRAY X-MP. The variable userpwd is the user's password. jobid is the name of the job on the X-MP. cputime is the cpu time limit and memory
is the maximum memory size allowed. hitcan.f is the compiler
input file containing the Fortran source code to be compiled.
hitcan.o is the object file created by the compiler and hitcan is the executable file. Note that the all of the files are assumed to reside in the user's home directory.

To execute HITCAN on the X-MP, the following script can be used:

```
# USER=userid PW=userpwd
# QSUB-r      jobid
# QSUB-lT     cputime
# QSUB -lM    memory
# QSUB-eo
set -x
```

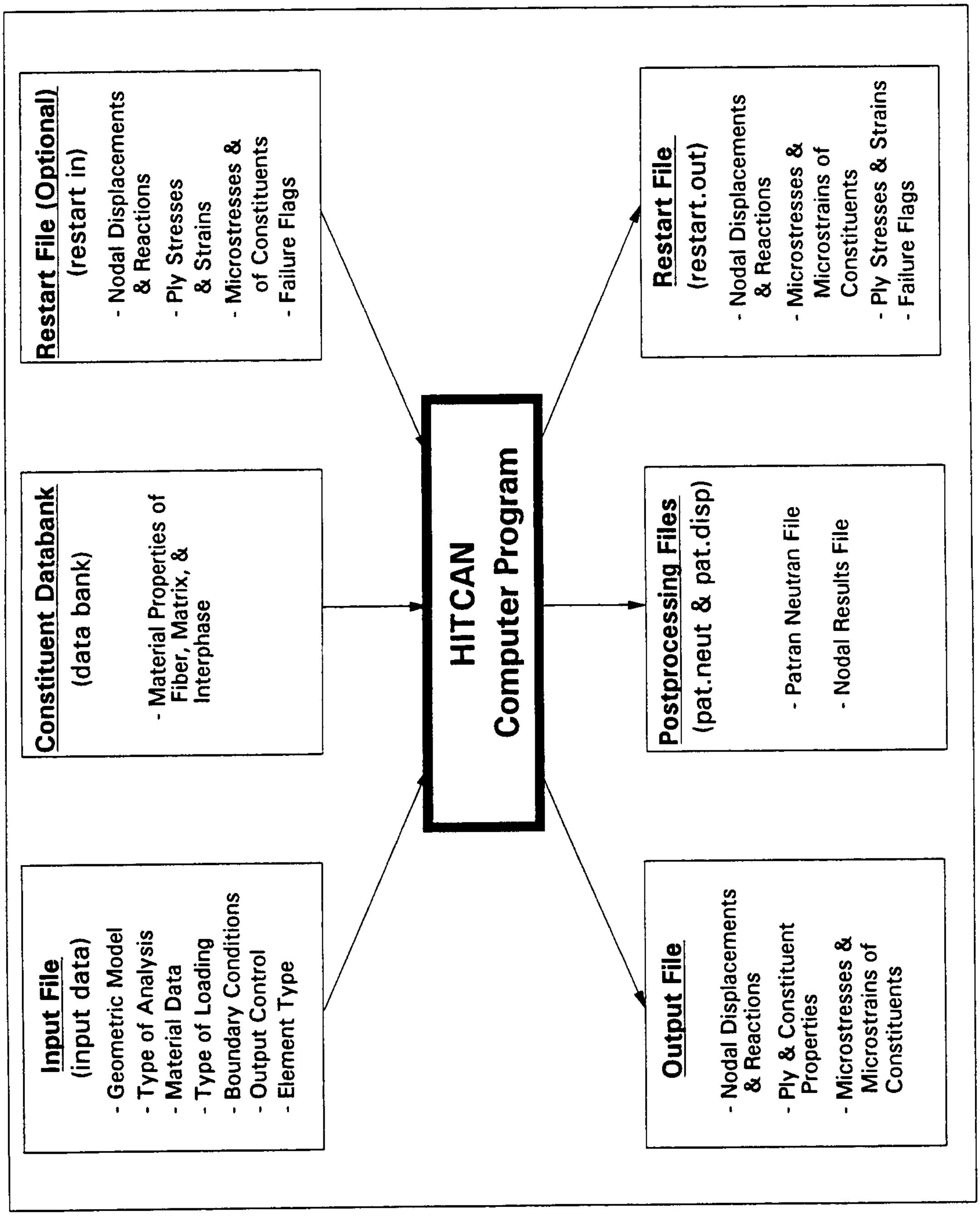

Figure 4.1: HITCAN/Input/Output File Structure

```
cp /aerospace2/userid/restart.in  fort.68
cp /aerospace2/userid/data.bank  fort.70
/aerospace2/userid/hitcan < /aerospace/userid/input.data

cp fort.18  /aerospace2/userid/pat.neut
cp fort.68  /aerospace2/userid/restart.out
cp fort.76  /aerospace2/userid/pat.disp
exit
```

To compile and load HITCAN on the CRAY Y-MP, the script below can be used:

```
# USER=userid PW=userpwd
# QSUB-r      jobid
# QSUB-lT     cputime
# QSUB -lM    memory
# QSUB-eo
set -x
cft -d p /wrk/userid/hitcan.f
segldr -o /wrk/userid/hitcan /wrk/userid/hitcan.o
exit
```

Here userid is the user's id on the Y-MP and userpwd is the user's password on the Y-MP. Note all of the files are assumed to reside in the user's workspace on the Y-MP. To execute HITCAN on the Y-MP, the following script can be used:

```
# USER=userid PW=userpwd
# QSUB-r      jobid
# QSUB-lT     cputime
# QSUB -lM    memory
# QSUB-eo
set -x
cd $W
mkdir tmp $$
cd tmp$$
cp /wrk/userid/restart.in  fort.68
cp /wrk/userid/data.bank  fort.70
/wrk/userid/hitcan < /wrk/userid/input.data
cp fort.18  /wrk/userid/pat.neut
cp fort.68  /wrk/userid/restart.out
cp fort.76  /wrk/userid/pat.disp
cd /wrk/userid
rm -fr tmp$$
exit
```

Here all of the underlined variables are the same as before.

CHAPTER 5

OUTPUT DESCRIPTION

The following is a description of the HITCAN output.

1. Echo print of the input dataset to HITCAN prior to interpretation by HITCAN. This is triggered by specifying the program option card ECHO.

2. HITCAN logo and version number.

3. A list of the program option cards specified.

4. A summary of the model and load data input.

5. Number of words required to perform the analysis. If there are more words required for memory, a message is printed specifying the number of additional words needed.

6. Description of the finite element model created, including the ply layup for each node. Also, the corresponding temperature and pressure at each node are listed, if program option cards TEMPERATURE or PRESSURE are specified.

7. The record of execution beginning at the first load step is given for each load increment. By setting the variable arrays NPRT, NPRTS, NPRTP, and NPPLY the user can specify the output for each increment. NPRT(1,I) is the initial node of set I at which displacement output is desired, NPRT(2,I) is the final node. NPRTS is an array containing the nodes selected for output of the ply stresses. As in NPRT, NPRTS(1,I) is the initial node and NPRTS(2,1) is the final node. By specifying NPRTP the user can select sets of nodes at which ply properties will be output. NPPLY contains the plies selected for output. NPPLY(1,J) is the initial ply and NPPLY(2,J) is the final ply. For NPRT, NPRTS, NPRTP, and NPPLY a maximum of 10 sets in each is allowed. These variables are specified in card group 42.

8. If a modal analysis is performed, the following information is given:

   a) The eigenvalue number and value.
   b) The corresponding frequency in both radians per time and cycles per time.
   c) The corresponding eigenvector, normalized so that the Lnorm is 1.0.
   d) The generalized mass associate with the normalization of the eigenvector.

9. If a buckling analysis is performed, the following information is given:

   a) The eigenvalue number and value.
   b) The corresponding eigenvector, normalized so that the Lnorm is 1.0.

CHAPTER 6

EXAMPLE PROBLEM #1

Example #1 demonstrates the thermal analysis of a composite shell structure using the HITCAN code. A curved shell (40 degree segment) has a radius of 120 in., a width of 120 in., and a thickness of 0.8 in. Both straight edges are clamped and both curved edges are free. Initially the shell is subjected to a temperature gradient of 20 deg. F. After 10 sec., an external pressure load of 0.1 psi is applied to the top surface. The shell is made of Sic/Ti-15-3-3-3 composite material (Silicon Carbide fiber, Titanium matrix with 15% Vanadium, 3% Aluminum, 3% Chromium, and 3% Tin, and interphase with average properties of the fiber and the matrix). The composite laminate consists of 4 plies (0/0/90/90) of equal thickness with 0.5 fiber volume ratio. The ply layup is such that the 0 degree plies are at the top and the 90 degree plies are on the bottom. The geometry, boundary conditions, loading, and ply layup are shown in Figure 6.1. The finite element model is shown in Figure 6.2. A portion of the output is shown after the input deck.

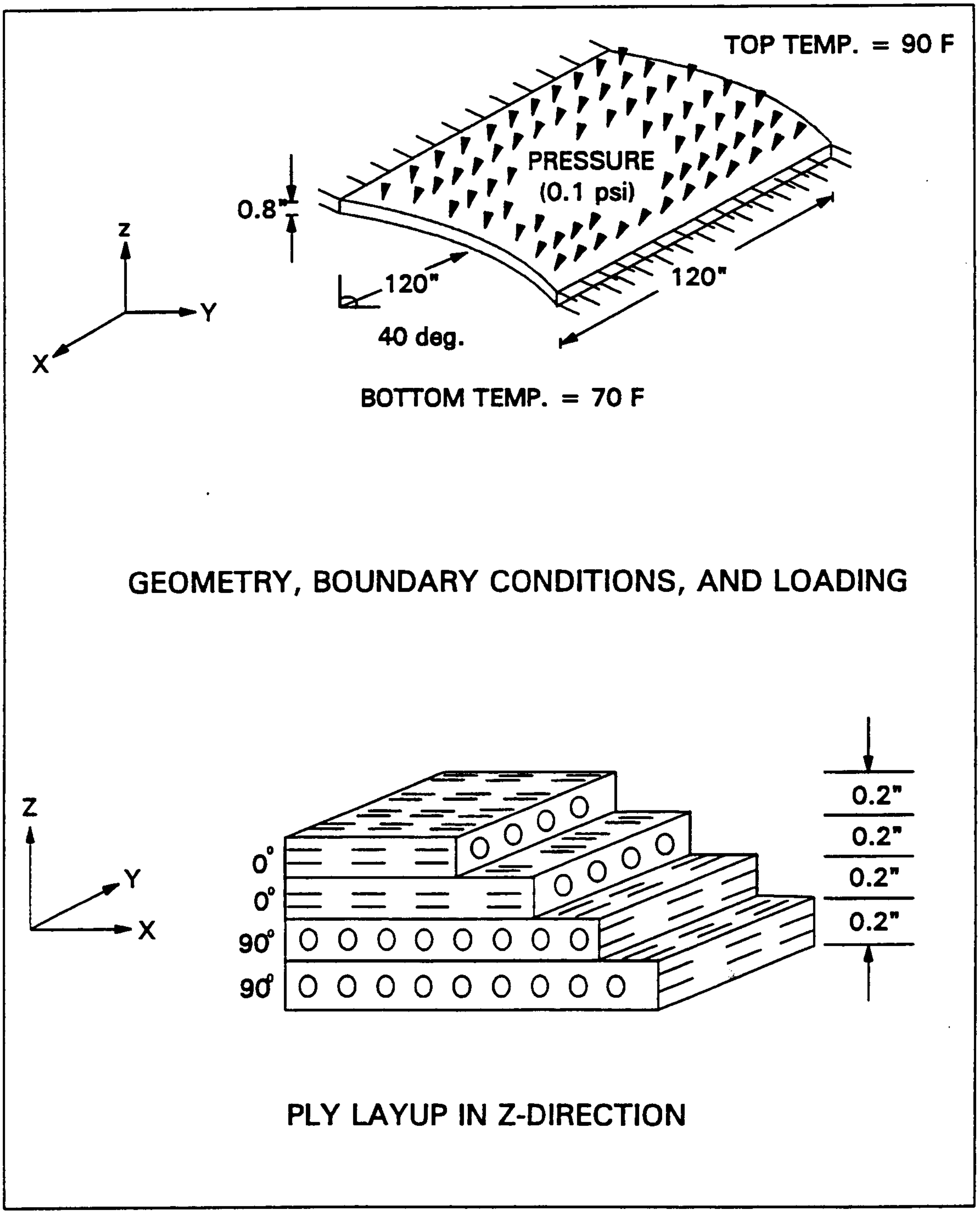

Figure 6.1: Example Problem Number 1

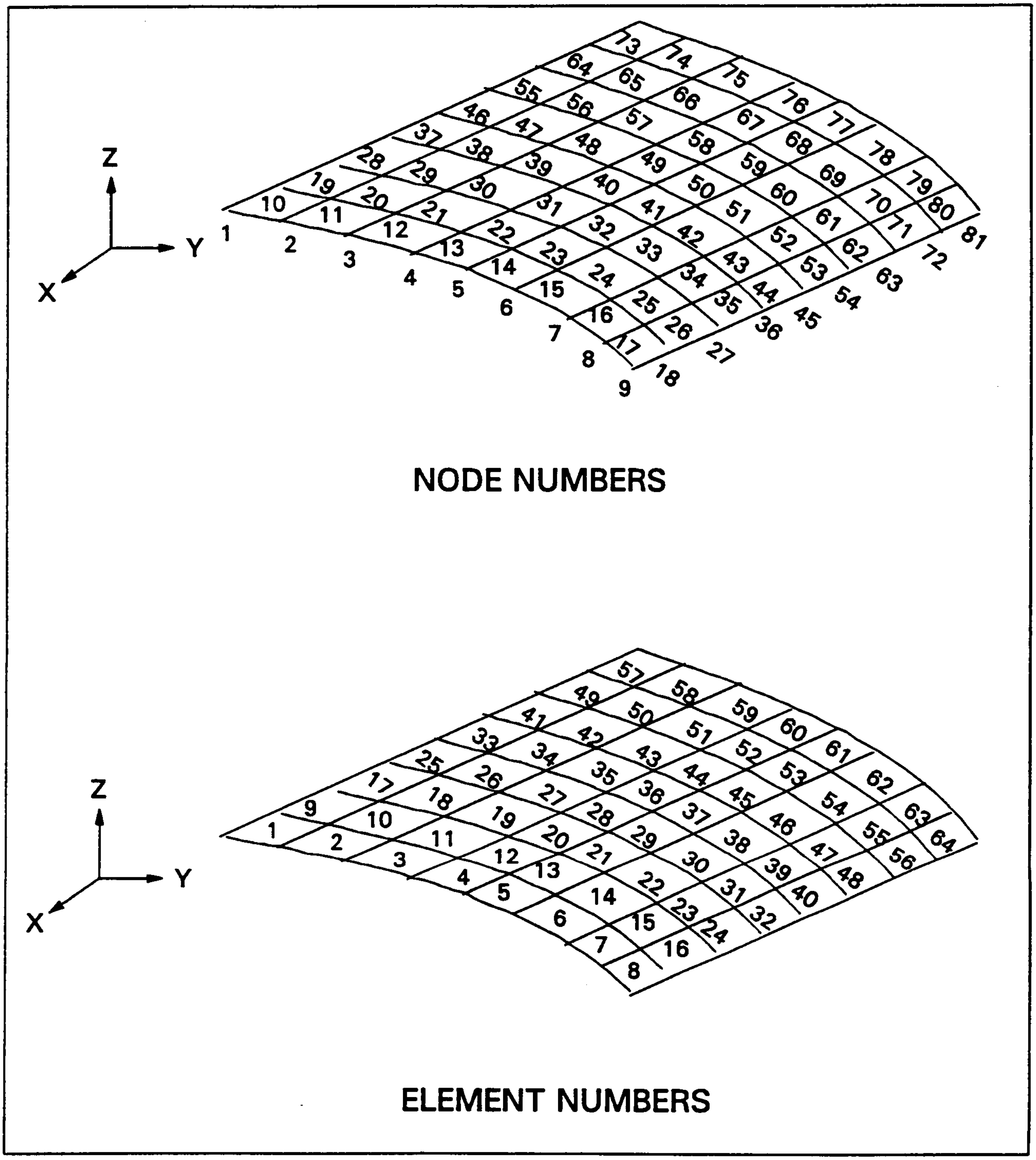

Figure 6.2: Finite Element Mesh For Example Number 1

INPUT DECK DESCRIPTION

PROGRAM OPTION CARDS

The program option cards chosen are:

TITLE
SPLATE
PLATE
PLYORDER
UNSYMMETRICAL
PRESSURE
TEMPERATURE
ENDOPTION

CARD GROUP 1

The number of material systems (plies) to be described in Card Group 28 of this input deck is 2. One material system is required for the ply with a fiber orientation angle of 0°, another material system is required for the ply with a fiber orientation angle of 90°.

CARD GROUP 5

Two cross-sections will be used to define the shell, this is indicated by NSECT = 2. Since, the model is described by the input X, Y, Z, and TB, IGRD is set to 4. The number of nodes along the x-axis is 9, so IU is set to 9. Nine nodes are needed along the y-axis, so JU is equal to 9. The finite element model is to begin at x=0.0 in. and end at x=120.0 in. These values are the variables XBEG and XEND.

CARD GROUP 6

The number of plies for one-half of the wall thickness (MAXPLY) is set to 2. This means that the number of plies for the bottom half of the shell will be 2.

CARD GROUP 7

Since the program option card UNSYMMETRICAL was specified, the number of plies for the top half of the shell is required. Because the ply layup is to consist of 4 plies, and because MAXPLY is equal to 2, the variable LMAX is set to 2.

CARD GROUP 10

In the this card group the number of load steps (NTISTP) is set to 2. Since the degradation of material properties due to cumulative mechanical/thermal load cycles is not to be included in this analysis, the number of mechanical cycles (NMECHC) is set to 1, and the number of thermal cycles (NTHERC) is also set to 1. The number of load increments (LINC) between load steps is 2. Since a restart file is not desired, the variable MSTART is set to 20. The variable MITER, the maximum number of iterations allowed for global convergence, is set to 10. The tolerance on global convergence (TOL) is set to 1.0.

CARD GROUP 16

The number of pressure data sets (NPRES) is 0, since there are no edge loads in this analysis.

CARD GROUP 17

The number of temperature data sets (NTEMP) is 0, since the temperature is input at the input points.

CARD GROUP 19

The number of boundary condition data sets (NBC) is 11.

CARD GROUP 27

The array MSECT is set equal to (5, 5), thus each cross-section will be defined by 5 points. The next card is the number of elements between cross-section (NXSPC), in this example it is 8. Input for the two cross-sections is provided in cross-section mid-plane and thickness form (specified by IGRD = 4). The next 5 records are the points of the first cross-section. The seventh record is the number of elements between the next 2 cross-sections. Since there is only 1 cross-section left the variable (NXSPC) is set to 0. The final 5 records in this card group represent the geometry of the second cross-section.

CARD GROUP 28

The number of different material systems is 2. Each material system is represented by two records, thus four lines are required. The first record defines the location of the ply on the model by percent of thickness, length, and width. The first two values on this record refer to the initial and final percent thickness of the thickest grid point of the model. The next four values are the initial and final percent width and initial and final percent length. Since both plies are to be used over the entire shell, this record has the values 0.0, 100.0, 0.0, 100.0, 0.0, and 100.0. The second record specifies fiber type, matrix type, ply thickness, void volume ratio, fiber volume ratio, and orientation angle in degrees relative to the structural x-axis. Here both plies are identical, except for the fiber orientation angle. The fibers of the bottom plies are along the x-axis, while the top plies are transverse to the x-axis.

CARD GROUP 29

The ply stack-up order for the bottom half of the shell is designated by 2 plies starting at the bottom surface. This layup is in the array MPLY. MPLY is equal to (2, 2), where these values are the material system identification numbers.

CARD GROUP 30

The ply stack-up order for the top half of the shell is designated by 2 plies starting at the top surface. This layup is in the array NPLY. NPLY is equal to (1, 1), where these values are the material system identification numbers.

CARD GROUP 32

The time at each load step is given in this card group.

CARD GROUP 33

Since the program option cards PRESSURE and TEMPERATURE were used, this group must be given. In this card group the temperature and pressure are given using the variables TL, TU, PL, and PU. Each line consist of the variables TL, TU, PL, and PU. The number of lines in this card group is (no. of load steps) x (number of input sections) x (number of points per input section); i. e., 2 x 2 x 5 = 20.

CARD GROUP 41

This CARD GROUP contains the boundary condition data. Each record consist of the beginning node number, the ending node number, the node numbering increment, and the degree-of-freedom which is constrained.

CARD GROUP 42

This card group controls the output. The nodal displacements are desired at nodes 5 through 32, 37 through 45, and 50 through 77. The ply stresses are desired at node 41. Also, a PATRAN results file containing nodal displacements is desired at the end of the analysis.

INPUT DECK FOR PROBLEM #1

Note that the Card Group Nos. are not part of the input file.

```
    ------------------ BLOCK #1   PROGRAM OPTION CARDS -------------------
    TITLE=CYLINDRICAL SHELL WITH PRESSURE AND TEMPERATURE LOADING
    SPLATE MODEL OPTION
    PLATE
    PLYORDER
    UNSYMMETRICAL
    PRESSURE
    TEMPERATURE
    ENDOPTION
    ------------------ BLOCK #2   CARD GROUPS --------------------------
CARD
GROUP
NO.
             1         2         3         4         5         6         7
    1........0.........0.........0.........0.........0.........0.........0.

 1-    2
 5-    2
 5-    4    9    9
 5-       .0     120.
 6-    2
 7-    2
10-    2    1    1    2   20   10
10-        1.
16-    0
17-    0
19-   10
27-    5    5
27-    4
27-        0.  -41.68   236.4      .8
27-        0.  -20.92   239.1      .8
27-        0.      0.    240.      .8
27-        0.   20.92   239.1      .8
27-        0.   41.68   236.4      .8
27-    0
27-      120.  -41.68   236.4      .8
27-      120.  -20.92   239.1      .8
27-      120.      0.    240.      .8
27-      120.   20.92   239.1      .8
27-      120.   41.68   236.4      .8
28-          .0      100.        .0      100.        .0      100.
28- SICA TI15          .2        .0        .5       0.
28-          .0      100.        .0      100.        .0      100.
28- SICA TI15          .2        .0        .5      90.
```

```
CARD
GROUP
NO.
             1         2         3         4         5         6         7
    1.........0.........0.........0.........0.........0.........0.........0.

29-    2   2
30-    1   1
32-         0.       10.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       0.
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
33-        70.       90.        0.       .1
41-    9 81   9   1
41-    9 81   9   2
41-    9 81   9   3
41-    9 81   9   4
41-    9 81   9   5
41-    1 73   9   1
41-    1 73   9   2
41-    1 73   9   3
41-    1 73   9   4
41-    1 73   9   5
42-    5 32  37  45  50  77
42-   41 41
42-
42-
42-       10.
```

HITCAN OUTPUT SUMMARY

CYLINDRICAL SHELL WITH PRESSURE AND TEMPERATURE LOADING

INITIAL LOAD

PLY STRESSES (in psi. units) IN THE MATERIAL COORDINATE SYSTEM FOR NODE 41

PLY NO.	SIGL-11	SIGL-22	SIGL-33	SIGL-12	SIGL-23	SIGL-
1	-0.144E+04	-0.264E+04	0.000E+00	0.133E-04	-0.509E-09	-0.566E
2	-0.156E+04	-0.156E+04	0.000E+00	0.678E-05	-0.109E-08	-0.121E
3	0.205E+03	-0.151E+04	0.000E+00	-0.215E-06	-0.121E-08	0.109E
4	0.199E+04	-0.149E+04	0.000E+00	0.634E-05	-0.566E-09	0.589E

DISPLACEMENTS AFTER THE INITIAL LOAD AT SELECTED NODES

NODE NO.	X (in.)	Y (in.)	Z (in.)	THETA-X (rad.)	THETA-Y (rad.)	THETA- (rad.
5	-0.120E-01	-0.215E-10	0.735E-01	0.729E-11	-0.232E-02	0.994E-
6	-0.114E-01	0.220E-02	0.661E-01	-0.147E-02	-0.227E-02	-0.227E-
7	-0.961E-02	0.311E-02	0.447E-01	-0.274E-02	-0.164E-02	-0.658E-
8	-0.667E-02	0.178E-02	0.149E-01	-0.298E-02	-0.131E-02	-0.187E-
9	-0.587E-26	-0.122E-25	0.239E-26	-0.519E-26	-0.651E-27	-0.413E-
10	-0.362E-25	0.103E-24	0.168E-25	0.790E-26	-0.202E-27	0.169E-
11	-0.342E-02	-0.144E-03	0.217E-01	0.389E-02	0.285E-03	0.217E-
12	-0.648E-02	-0.221E-02	0.608E-01	0.352E-02	-0.418E-03	0.112E-
13	-0.811E-02	-0.196E-02	0.904E-01	0.199E-02	-0.107E-02	0.293E-
14	-0.867E-02	-0.268E-10	0.101E+00	0.553E-11	-0.127E-02	0.492E-
15	-0.811E-02	0.196E-02	0.904E-01	-0.199E-02	-0.107E-02	-0.293E-
16	-0.648E-02	0.221E-02	0.608E-01	-0.352E-02	-0.418E-03	-0.112E-
17	-0.342E-02	0.144E-03	0.217E-01	-0.389E-02	0.285E-03	-0.217E-
18	-0.362E-25	-0.103E-24	0.168E-25	-0.790E-26	-0.202E-27	-0.169E-
19	-0.223E-25	0.117E-24	0.183E-25	0.483E-26	-0.352E-27	0.726E-
20	-0.206E-02	0.262E-03	0.194E-01	0.379E-02	-0.586E-04	0.186E-
21	-0.382E-02	-0.171E-02	0.629E-01	0.452E-02	0.170E-03	0.866E-
22	-0.509E-02	-0.184E-02	0.100E+00	0.279E-02	-0.308E-03	0.398E-
23	-0.551E-02	-0.249E-10	0.115E+00	0.370E-11	-0.513E-03	0.946E-
24	-0.509E-02	0.184E-02	0.100E+00	-0.279E-02	-0.308E-03	-0.398E-
25	-0.382E-02	0.171E-02	0.629E-01	-0.452E-02	0.170E-03	-0.866E-
26	-0.206E-02	-0.262E-03	0.194E-01	-0.379E-02	-0.586E-04	-0.186E-
27	-0.223E-25	-0.117E-24	0.183E-25	-0.483E-26	-0.352E-27	-0.726E-
28	-0.105E-25	0.118E-24	0.180E-25	0.309E-26	0.362E-28	0.637E-
29	-0.977E-03	0.326E-03	0.193E-01	0.346E-02	0.400E-04	0.438E-
30	-0.183E-02	-0.153E-02	0.620E-01	0.464E-02	-0.486E-04	0.378E-

31	-0.242E-02	-0.180E-02	0.103E+00	0.306E-02	-0.527E-04	0.179E-04
32	-0.265E-02	-0.136E-10	0.119E+00	0.155E-11	-0.700E-04	0.179E-11
37	-0.428E-33	0.117E-24	0.183E-25	0.368E-26	-0.798E-34	0.288E-11
38	0.321E-12	0.387E-03	0.188E-01	0.367E-02	0.404E-12	-0.785E-12
39	-0.156E-11	-0.155E-02	0.625E-01	0.469E-02	-0.780E-12	0.149E-11
40	-0.165E-11	-0.179E-02	0.103E+00	0.324E-02	-0.901E-12	-0.857E-12
41	0.310E-14	0.231E-14	0.120E+00	0.120E-14	0.561E-14	0.148E-11
42	0.166E-11	0.179E-02	0.103E+00	-0.324E-02	0.896E-12	-0.856E-12
43	0.156E-11	0.155E-02	0.625E-01	-0.469E-02	0.777E-12	0.149E-11
44	-0.319E-12	-0.387E-03	0.188E-01	-0.367E-02	-0.401E-12	-0.786E-12
45	0.428E-33	-0.117E-24	0.183E-25	-0.368E-26	0.798E-34	0.288E-11
50	0.265E-02	0.136E-10	0.119E+00	-0.154E-11	0.700E-04	0.179E-11
51	0.242E-02	0.180E-02	0.103E+00	-0.306E-02	0.527E-04	0.179E-04
52	0.183E-02	0.153E-02	0.620E-01	-0.464E-02	0.486E-04	0.378E-04
53	0.977E-03	-0.326E-03	0.193E-01	-0.346E-02	-0.400E-04	0.438E-04
54	0.105E-25	-0.118E-24	0.180E-25	-0.309E-26	-0.362E-28	0.637E-04
55	0.223E-25	0.117E-24	0.183E-25	0.483E-26	0.352E-27	-0.726E-04
56	0.286E-02	0.262E-03	0.194E-01	0.379E-02	0.586E-04	-0.186E-03
57	0.382E-02	-0.171E-02	0.629E-01	0.452E-02	-0.170E-03	-0.866E-04
58	0.509E-02	-0.184E-02	0.100E+00	0.279E-02	0.308E-03	-0.398E-04
59	0.551E-02	0.249E-10	0.115E+00	-0.370E-11	0.513E-03	0.946E-12
60	0.509E-02	0.184E-02	0.100E+00	-0.279E-02	0.308E-03	0.398E-04
61	0.382E-02	0.171E-02	0.629E-01	-0.452E-02	-0.170E-03	0.866E-04
62	0.286E-02	-0.262E-03	0.194E-01	-0.379E-02	0.586E-04	0.186E-03
63	0.223E-25	-0.117E-24	0.183E-25	-0.483E-26	0.352E-27	0.726E-04
64	0.362E-25	0.103E-24	0.168E-25	0.790E-26	0.202E-27	-0.169E-03
65	0.342E-02	-0.144E-03	0.217E-01	0.389E-02	-0.285E-03	-0.217E-03
66	0.648E-02	-0.221E-02	0.608E-01	0.352E-02	0.418E-03	-0.112E-03
67	0.811E-02	-0.196E-02	0.904E-01	0.199E-02	0.107E-02	-0.293E-04
68	0.867E-02	0.268E-10	0.101E+00	-0.551E-11	0.127E-02	0.491E-11
69	0.811E-02	0.196E-02	0.904E-01	-0.199E-02	0.107E-02	0.293E-04
70	0.648E-02	0.221E-02	0.608E-01	-0.352E-02	0.418E-03	0.112E-03
71	0.342E-02	0.144E-03	0.217E-01	-0.389E-02	-0.285E-03	0.217E-03
72	0.362E-25	-0.103E-24	0.168E-25	-0.790E-26	0.202E-27	0.169E-03
73	0.587E-26	0.122E-25	0.239E-26	0.519E-26	0.651E-27	-0.413E-03
74	0.667E-02	-0.178E-02	0.149E-01	0.298E-02	0.131E-02	-0.187E-03
75	0.961E-02	-0.311E-02	0.447E-01	0.274E-02	0.164E-02	-0.658E-04
76	0.114E-01	-0.228E-02	0.661E-01	0.147E-02	0.227E-02	-0.227E-04
77	0.128E-01	0.215E-10	0.735E-01	-0.730E-11	0.232E-02	0.994E-11

TIME REQUIRED TO : LOOP THRU METCAN 16.911 SEC.
DETER. THE DISPL. IN MHOST 2.918 SEC.
ANALYSIZE THE FIRST TIME STEP 37.624 SEC.

H I T C A N   O U T P U T   S U M M A R Y

CYLINDRICAL SHELL WITH PRESSURE AND TEMPERATURE LOADING

LOAD INCREMENT NUMBER	1
TIME STEP	2
CYCLE NUMBER	1
TIME	5.0000000

PLY STRESSES (in psi. units) IN THE MATERIAL COORDINATE SYSTEM FOR NODE 41

PLY NO.	SIGL-11	SIGL-22	SIGL-33	SIGL-12	SIGL-23	SIGL-1
1	-0.144E+04	-0.265E+04	0.000E+00	0.133E-04	-0.508E-09	-0.566E
2	-0.156E+04	-0.157E+04	0.000E+00	0.681E-05	-0.109E-08	-0.121E
3	0.185E+03	-0.151E+04	0.000E+00	-0.325E-06	-0.121E-08	0.109E
4	0.197E+04	-0.149E+04	0.000E+00	0.616E-05	-0.566E-09	0.588E

H I T C A N   O U T P U T   S U M M A R Y

CYLINDRICAL SHELL WITH PRESSURE AND TEMPERATURE LOADING

LOAD INCREMENT NUMBER	1
TIME STEP	2
CYCLE NUMBER	1
TIME	5.0000000

TOTAL DISPLACEMENTS FOR SELECTED NODES

NODE NO.	X (in.)	Y (in.)	Z (in.)	THETA-X (rad.)	THETA-Y (rad.)	THETA- (rad.
5	-0.120E-01	-0.213E-10	0.732E-01	0.742E-11	-0.232E-02	0.995E-
6	-0.114E-01	0.220E-02	0.658E-01	-0.147E-02	-0.227E-02	-0.227E-
7	-0.961E-02	0.311E-02	0.446E-01	-0.273E-02	-0.164E-02	-0.659E-
8	-0.667E-02	0.178E-02	0.149E-01	-0.298E-02	-0.131E-02	-0.187E-
9	-0.590E-26	-0.121E-25	0.237E-26	-0.519E-26	-0.651E-27	-0.414E-
10	-0.363E-25	0.103E-24	0.167E-25	0.789E-26	-0.203E-27	0.169E-
11	-0.342E-02	-0.143E-03	0.216E-01	0.389E-02	0.284E-03	0.217E-
12	-0.648E-02	-0.222E-02	0.607E-01	0.351E-02	-0.418E-03	0.112E-
13	-0.811E-02	-0.195E-02	0.902E-01	0.198E-02	-0.107E-02	0.2
14	-0.868E-02	-0.267E-10	0.101E+00	0.563E-11	-0.127E-02	0.4

15	-0.811E-02	0.195E-02	0.902E-01	-0.198E-02	-0.187E-02	-0.294E-04
16	-0.648E-02	0.220E-02	0.687E-01	-0.351E-02	-0.418E-03	-0.112E-03
17	-0.342E-02	0.143E-03	0.216E-01	-0.389E-02	0.284E-03	-0.217E-03
18	-0.363E-25	-0.183E-24	0.167E-25	-0.789E-26	-0.283E-27	-0.169E-03
19	-0.223E-25	0.117E-24	0.183E-25	0.482E-26	-0.352E-27	0.727E-04
20	-0.206E-02	0.262E-03	0.194E-01	0.378E-02	-0.585E-04	0.186E-03
21	-0.382E-02	-0.170E-02	0.627E-01	0.452E-02	0.170E-03	0.867E-04
22	-0.509E-02	-0.183E-02	0.108E+00	0.279E-02	-0.308E-03	0.398E-04
23	-0.551E-02	-0.249E-10	0.115E+00	0.376E-11	-0.513E-03	0.952E-12
24	-0.509E-02	0.183E-02	0.108E+00	-0.279E-02	-0.308E-03	-0.398E-04
25	-0.382E-02	0.170E-02	0.627E-01	-0.452E-02	0.170E-03	-0.867E-04
26	-0.206E-02	-0.262E-03	0.194E-01	-0.378E-02	-0.585E-04	-0.186E-03
27	-0.223E-25	-0.117E-24	0.183E-25	-0.482E-26	-0.352E-27	-0.727E-04
28	-0.105E-25	0.117E-24	0.180E-25	0.307E-26	0.361E-28	0.637E-04
29	-0.978E-03	0.327E-03	0.193E-01	0.345E-02	0.400E-04	0.431E-04
30	-0.183E-02	-0.152E-02	0.619E-01	0.463E-02	-0.486E-04	0.378E-04
31	-0.242E-02	-0.179E-02	0.103E+00	0.305E-02	-0.528E-04	0.179E-04
32	-0.265E-02	-0.136E-10	0.119E+00	0.158E-11	-0.708E-04	0.188E-11
37	-0.428E-33	0.117E-24	0.182E-25	0.367E-26	-0.797E-34	0.281E-11
38	0.328E-12	0.388E-03	0.188E-01	0.366E-02	0.399E-12	-0.795E-12
39	-0.156E-11	-0.155E-02	0.624E-01	0.468E-02	-0.795E-12	0.158E-11
40	-0.165E-11	-0.179E-02	0.103E+00	0.323E-02	-0.913E-12	-0.866E-12
41	0.309E-14	0.231E-14	0.120E+00	0.121E-14	0.560E-14	0.148E-11
42	0.166E-11	0.179E-02	0.103E+00	-0.323E-02	0.907E-12	-0.865E-12
43	0.156E-11	0.155E-02	0.624E-01	-0.468E-02	0.793E-12	0.158E-11
44	-0.326E-12	-0.388E-03	0.188E-01	-0.366E-02	-0.396E-12	-0.796E-12
45	0.428E-33	-0.117E-24	0.182E-25	-0.367E-26	0.797E-34	0.281E-11
50	0.265E-02	0.136E-10	0.119E+00	-0.157E-11	0.708E-04	0.188E-11
51	0.242E-02	0.179E-02	0.103E+00	-0.305E-02	0.528E-04	0.179E-04
52	0.183E-02	0.152E-02	0.619E-01	-0.463E-02	0.486E-04	0.378E-04
53	0.978E-03	-0.327E-03	0.193E-01	-0.345E-02	-0.400E-04	0.431E-04
54	0.105E-25	-0.117E-24	0.180E-25	-0.307E-26	-0.361E-28	0.637E-04
55	0.223E-25	0.117E-24	0.183E-25	0.482E-26	0.352E-27	-0.727E-04
56	0.206E-02	0.262E-03	0.194E-01	0.378E-02	0.585E-04	-0.186E-03
57	0.382E-02	-0.170E-02	0.627E-01	0.452E-02	-0.170E-03	-0.867E-04
58	0.509E-02	-0.183E-02	0.108E+00	0.279E-02	0.308E-03	-0.398E-04
59	0.551E-02	0.249E-10	0.115E+00	-0.376E-11	0.513E-03	0.953E-12

60	0.509E-02	0.183E-02	0.100E+00	-0.279E-02	0.308E-03	0.390E-0
61	0.382E-02	0.170E-02	0.627E-01	-0.452E-02	-0.170E-03	0.867E-0
62	0.206E-02	-0.262E-03	0.194E-01	-0.378E-02	0.585E-04	0.186E-03
63	0.223E-25	-0.117E-24	0.183E-25	-0.482E-26	0.352E-27	0.727E-0
64	0.363E-25	0.103E-24	0.167E-25	0.789E-26	0.203E-27	-0.169E-03
65	0.342E-02	-0.143E-03	0.216E-01	0.389E-02	-0.284E-03	-0.217E-03
66	0.648E-02	-0.220E-02	0.687E-01	0.351E-02	0.418E-03	-0.112E-03
67	0.811E-02	-0.195E-02	0.902E-01	0.198E-02	0.107E-02	-0.294E-04
68	0.868E-02	0.267E-10	0.101E+00	-0.561E-11	0.127E-02	0.492E-11
69	0.811E-02	0.195E-02	0.902E-01	-0.198E-02	0.107E-02	0.294E-04
70	0.648E-02	0.220E-02	0.687E-01	-0.351E-02	0.418E-03	0.112E-03
71	0.342E-02	0.143E-03	0.216E-01	-0.389E-02	-0.284E-03	0.217E-03
72	0.363E-25	-0.103E-24	0.167E-25	-0.789E-26	0.203E-27	0.169E-03
73	0.590E-26	0.121E-25	0.237E-26	0.519E-26	0.651E-27	-0.414E-03
74	0.667E-02	-0.178E-02	0.149E-01	0.298E-02	0.131E-02	-0.187E-03
75	0.961E-02	-0.311E-02	0.446E-01	0.273E-02	0.164E-02	-0.659E-04
76	0.114E-01	-0.220E-02	0.658E-01	0.147E-02	0.227E-02	-0.227E-04
77	0.120E-01	0.213E-10	0.732E-01	-0.743E-11	0.232E-02	0.995E-11

TIME REQUIRED TO EVALUATE THIS LOAD INCREMENT 71.790 SEC.

H I T C A N   O U T P U T   S U M M A R Y

CYLINDRICAL SHELL WITH PRESSURE AND TEMPERATURE LOADING

LOAD INCREMENT NUMBER	2
TIME STEP	2
CYCLE NUMBER	1
TIME	10.0000000

PLY STRESSES (in psi. units) IN THE MATERIAL COORDINATE SYSTEM FOR NODE 41

PLY NO.	SIGL-11	SIGL-22	SIGL-33	SIGL-12	SIGL-23	SIGL-3
1	-0.143E+04	-0.266E+04	0.000E+00	0.133E-04	-0.508E-09	-0.566E
2	-0.156E+04	-0.158E+04	0.000E+00	0.685E-05	-0.109E-08	-0.121E
3	0.166E+03	-0.152E+04	0.000E+00	-0.435E-06	-0.122E-08	0.189E
4	0.195E+04	-0.149E+04	0.000E+00	0.597E-05	-0.566E-09	0.588E

H I T C A N   O U T P U T   S U M M A R Y

CYLINDRICAL SHELL WITH PRESSURE AND TEMPERATURE LOADING

LOAD INCREMENT NUMBER	2
TIME STEP	2
CYCLE NUMBER	1
TIME	10.0000000

TOTAL DISPLACEMENTS FOR SELECTED NODES

NODE NO.	X (in.)	Y (in.)	Z (in.)	THETA-X (rad.)	THETA-Y (rad.)	THETA-Z (rad.)
5	-0.120E-01	-0.210E-10	0.730E-01	0.756E-11	-0.233E-02	0.996E-11
6	-0.114E-01	0.219E-02	0.656E-01	-0.146E-02	-0.227E-02	-0.226E-04
7	-0.962E-02	0.310E-02	0.444E-01	-0.272E-02	-0.164E-02	-0.659E-04
8	-0.667E-02	0.178E-02	0.148E-01	-0.297E-02	-0.131E-02	-0.187E-03
9	-0.592E-26	-0.120E-25	0.235E-26	-0.518E-26	-0.650E-27	-0.414E-03
10	-0.363E-25	0.103E-24	0.167E-25	0.788E-26	-0.203E-27	0.169E-03
11	-0.342E-02	-0.143E-03	0.216E-01	0.388E-02	0.284E-03	0.217E-03
12	-0.649E-02	-0.220E-02	0.606E-01	0.350E-02	-0.418E-03	0.112E-03
13	-0.812E-02	-0.195E-02	0.900E-01	0.198E-02	-0.107E-02	0.294E-04
14	-0.868E-02	-0.265E-10	0.101E+00	0.573E-11	-0.127E-02	0.495E-11
15	-0.812E-02	0.195E-02	0.900E-01	-0.198E-02	-0.107E-02	-0.294E-04
16	-0.649E-02	0.220E-02	0.606E-01	-0.350E-02	-0.418E-03	-0.112E-03
17	-0.342E-02	0.143E-03	0.216E-01	-0.388E-02	0.284E-03	-0.217E-03
18	-0.363E-25	-0.103E-24	0.167E-25	-0.788E-26	-0.203E-27	-0.169E-03
19	-0.223E-25	0.117E-24	0.182E-25	0.480E-26	-0.352E-27	0.728E-04
20	-0.206E-02	0.263E-03	0.194E-01	0.377E-02	-0.583E-04	0.186E-03
21	-0.383E-02	-0.170E-02	0.626E-01	0.451E-02	0.170E-03	0.868E-04
22	-0.509E-02	-0.183E-02	0.100E+00	0.278E-02	-0.308E-03	0.398E-04
23	-0.552E-02	-0.248E-10	0.114E+00	0.382E-11	-0.513E-03	0.958E-12
24	-0.509E-02	0.183E-02	0.100E+00	-0.278E-02	-0.308E-03	-0.398E-04
25	-0.383E-02	0.170E-02	0.626E-01	-0.451E-02	0.170E-03	-0.868E-04
26	-0.206E-02	-0.263E-03	0.194E-01	-0.377E-02	-0.583E-04	-0.186E-03
27	-0.223E-25	-0.117E-24	0.182E-25	-0.480E-26	-0.352E-27	-0.728E-04
28	-0.105E-25	0.117E-24	0.188E-25	0.306E-26	0.361E-28	0.637E-04
29	-0.978E-03	0.327E-03	0.192E-01	0.344E-02	0.399E-04	0.431E-04
30	-0.183E-02	-0.152E-02	0.618E-01	0.462E-02	-0.486E-04	0.379E-04
31	-0.242E-02	-0.179E-02	0.103E+00	0.305E-02	-0.528E-04	0.179E-04
32	-0.265E-02	-0.136E-10	0.119E+00	0.160E-11	-0.701E-04	0.180E-11
37	-0.427E-33	0.117E-24	0.182E-25	0.366E-26	-0.796E-34	0.282E-11
38	0.335E-12	0.389E-03	0.188E-01	0.365E-02	0.394E-12	-0.885E-12

39	-0.156E-11	-0.154E-02	0.622E-01	0.467E-02	-0.811E-12	0.151E-11
40	-0.166E-11	-0.179E-02	0.103E+00	0.323E-02	-0.924E-12	-0.875E-12
41	0.308E-14	0.232E-14	0.119E+00	0.122E-14	0.557E-14	0.149E-11
42	0.166E-11	0.179E-02	0.103E+00	-0.323E-02	0.919E-12	-0.874E-12
43	0.156E-11	0.154E-02	0.622E-01	-0.467E-02	0.809E-12	0.151E-11
44	-0.333E-12	-0.389E-03	0.188E-01	-0.365E-02	-0.391E-12	-0.886E-12
45	0.427E-33	-0.117E-24	0.182E-25	-0.366E-26	0.796E-34	0.282E-11
50	0.265E-02	0.136E-10	0.119E+00	-0.159E-11	0.781E-04	0.180E-11
51	0.292E-02	0.179E-02	0.103E+00	-0.305E-02	0.528E-04	0.179E-04
52	0.183E-02	0.152E-02	0.618E-01	-0.462E-02	0.486E-04	0.579E-04
53	0.978E-03	-0.327E-03	0.192E-01	-0.344E-02	-0.399E-04	0.451E-04
54	0.105E-25	-0.117E-24	0.188E-25	-0.386E-26	-0.361E-28	0.657E-04
55	0.223E-25	0.117E-24	0.182E-25	0.480E-26	0.352E-27	-0.728E-04
56	0.206E-02	0.263E-03	0.194E-01	0.377E-02	0.583E-04	-0.186E-03
57	0.383E-02	-0.170E-02	0.626E-01	0.451E-02	-0.170E-03	-0.868E-04
58	0.509E-02	-0.183E-02	0.100E+00	0.278E-02	0.308E-03	-0.398E-04
59	0.552E-02	0.248E-10	0.114E+00	-0.381E-11	0.513E-03	0.959E-11
60	0.509E-02	0.183E-02	0.100E+00	-0.278E-02	0.308E-03	0.398E-04
61	0.383E-02	0.170E-02	0.626E-01	-0.451E-02	-0.170E-03	0.868E-04
62	0.206E-02	-0.263E-03	0.194E-01	-0.377E-02	0.583E-04	0.186E-03
63	0.223E-25	-0.117E-24	0.182E-25	-0.480E-26	0.352E-27	0.728E-04
64	0.363E-25	0.103E-24	0.167E-25	0.788E-26	0.203E-27	-0.169E-03
65	0.342E-02	-0.143E-03	0.216E-01	0.388E-02	-0.284E-03	-0.217E-03
66	0.649E-02	-0.220E-02	0.606E-01	0.350E-02	0.418E-03	-0.112E-03
67	0.812E-02	-0.195E-02	0.900E-01	0.198E-02	0.107E-02	-0.294E-04
68	0.868E-02	0.265E-10	0.101E+00	-0.571E-11	0.127E-02	0.495E-11
69	0.812E-02	0.195E-02	0.900E-01	-0.198E-02	0.107E-02	0.294E-04
70	0.649E-02	0.220E-02	0.606E-01	-0.350E-02	0.418E-03	0.112E-03
71	0.342E-02	0.143E-03	0.216E-01	-0.388E-02	-0.284E-03	0.217E-03
72	0.363E-25	-0.103E-24	0.167E-25	-0.788E-26	0.203E-27	0.169E-03
73	0.592E-26	0.120E-25	0.235E-26	0.518E-26	0.650E-27	-0.414E-03
74	0.667E-02	-0.178E-02	0.148E-01	0.297E-02	0.131E-02	-0.187E-03
75	0.962E-02	-0.310E-02	0.444E-01	0.272E-02	0.164E-02	-0.659E-04
76	0.114E-01	-0.219E-02	0.656E-01	0.146E-02	0.227E-02	-0.226E-04
77	0.120E-01	0.210E-10	0.730E-01	-0.756E-11	0.233E-02	0.996E-11

EXAMPLE PROBLEM #2

Example #2 demonstrates the basic characteristics of a dataset required to run the S3DSOLID model option in the HITCAN code. This second example is of a thick ring subjected to centrifugal loading at an angular velocity of 20,000 rpm. The ring has an inside radius of 2.875 in. and an outside radius of 3.475 in. The ring is made of Sic/Ti-15-3-3-3 composite material (Silicon Carbide fiber, Titanium matrix with 15% Vanadium, 3% Aluminum, 3% Chromium, and 3% Tin, and interphase with average properties of the fiber and the matrix). The composite laminate consists of 7 plies each with a fiber volume ratio of 0.5. All of the fibers have an orientation angle of 90 deg. w.r.t. the x-axis. Since this is an axisymmetric problem, only a small sector (3 degrees) of the ring was modeled. The geometry and the boundary conditions are shown in Figure 6.3. The finite element model is shown in Figures 6.4 and 6.5. A portion of the output is shown after the input deck.

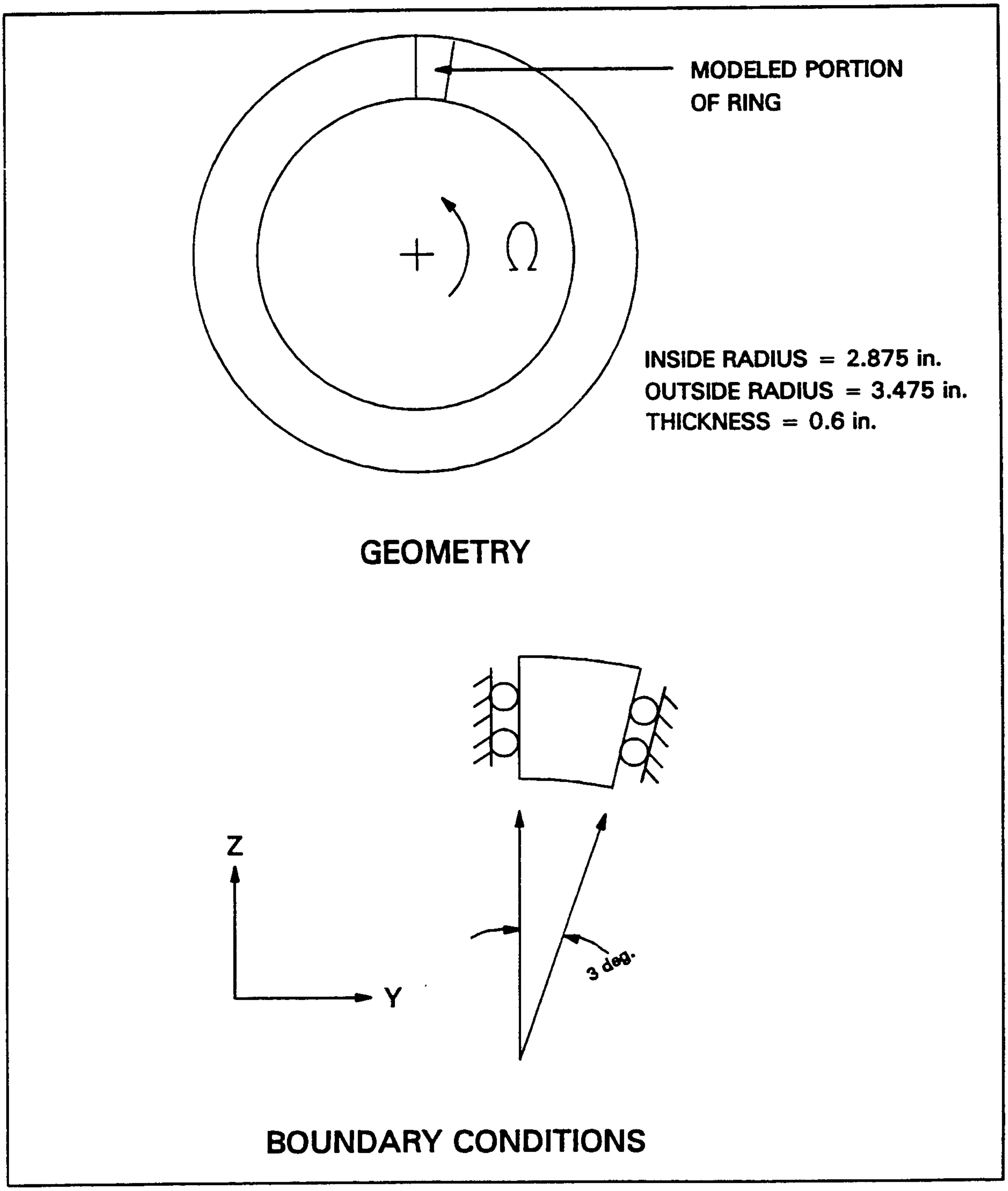

Figure 6.3: Example Problem Number 2

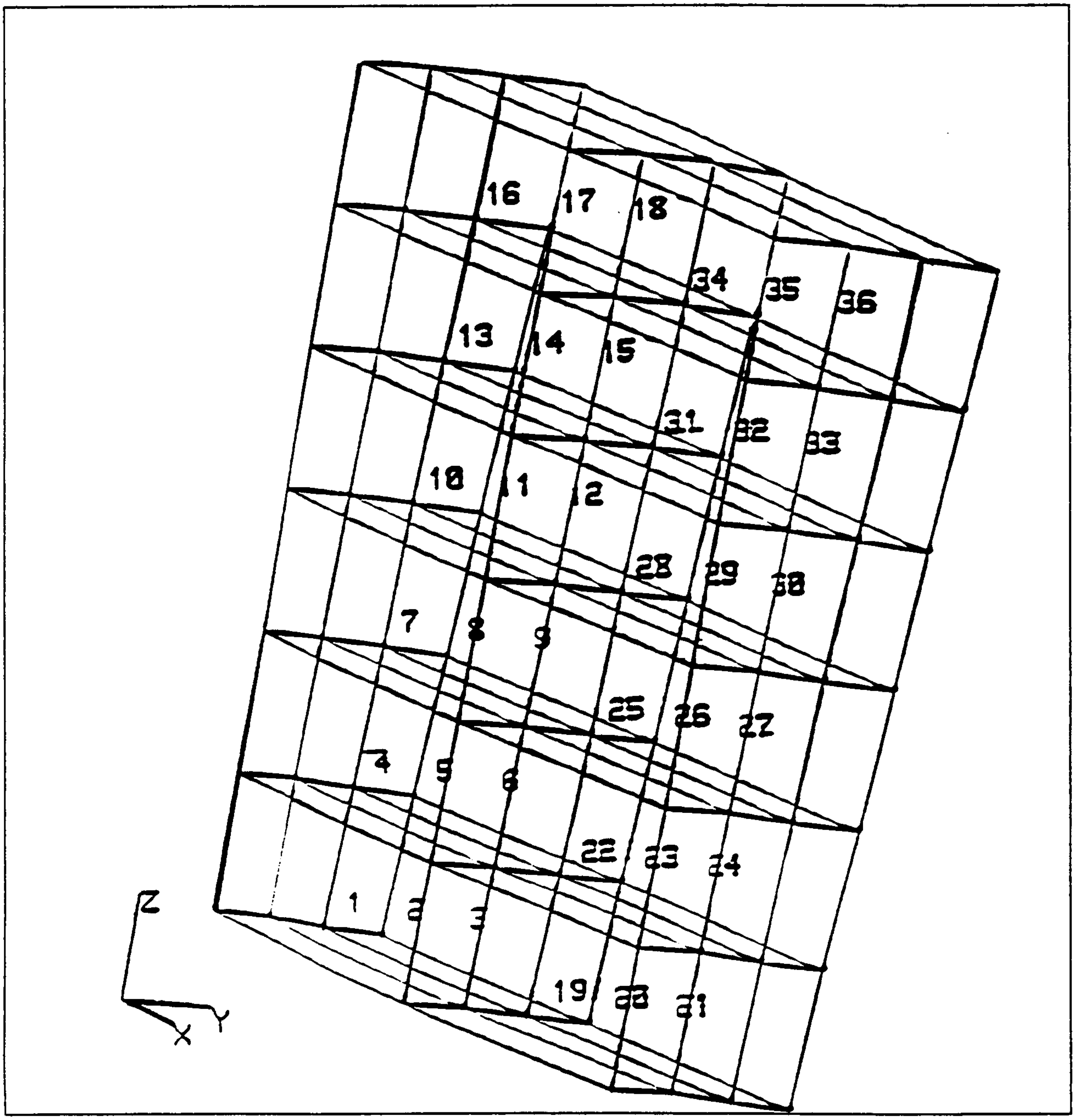

Figure 6.4: Element Numbers For Example Number 2

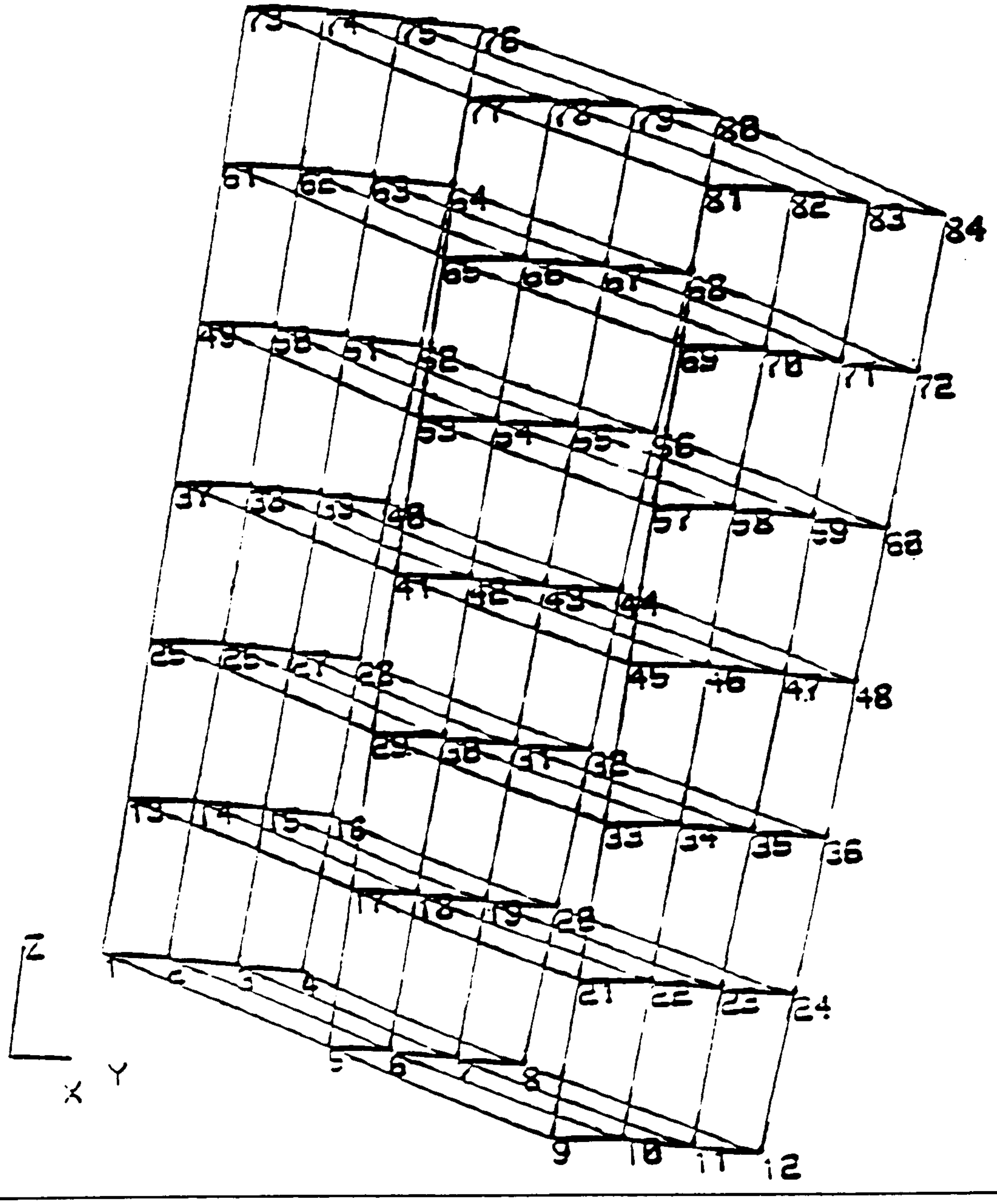

Figure 6.5: Node Numbers For Example Number 2

INPUT DECK DESCRIPTION

PROGRAM OPTION CARDS

The program option cards chosen are:

TITLE
S3DSOLID
BRICK
PLYORDER
UNSYMMETRICAL
TRANSFORMATION
ANGULAR
ENDOPTION

CARD GROUP 1

The number of material systems to be described in Card Group 28 of this input deck is 2. The two material systems are identical, except for the ply thicknesses. The first material system has a ply thickness of 0.05 in., the second has a ply thickness of 0.1 in.

CARD GROUP 4

Two input planes will be used to define the ring, this is indicated by NIPL = 2. The number of output sections (NOSC) was chosen to be 3. The number of elements along the y-axis is 3, so NEYY is set to 3. Six elements are needed through the thickness, so NETT is equal to 6.

CARD GROUP 6

The number of plies for one-half of the wall thickness (MAXPLY) is set to 4. This means that the number of plies for the bottom half of the ring will be 4.

CARD GROUP 7

Since the program option card UNSYMMETRICAL was specified, the number of plies for the top half of the ring needs to be given. Because the ply layup is to consist of 7 plies the variable LMAX is set to 3.

CARD GROUP 10

In the this card group the number of load steps (NTISTP) is set to 1, the number of mechanical cycles (NMECHC) is set to 1, and the number of thermal cycles (NTHERC) is also set to 1. The number of load increments (LINC) is 1. Since a restart file is not desired, the variable MSTART is set to 20. The variable MITER, the maximum number of iterations allowed for global convergence, is set to 10. The tolerance on global convergence (TOL) is set to 1.0.

CARD GROUP 18

The number of transformation data sets (NTR) is 1. Coordinate transformation is needed to apply skewed boundary conditions on the right edge of the sector.

CARD GROUP 19

The number of boundary condition data sets (NBC) is 11.

CARD GROUP 26

In this card group, the first card contains the number of elements between output sections and the x-coordinate of the output sections are specified. Between output sections 1 and 2, 2 elements are desired. Between sections 2 and 3, 4 elements are needed. Finally, between sections 3 and 4, 2 elements are needed. The array NXSPC will be equal to (2, 4, 2). The x-coordinate of each output section is in the array X. This array has the values (.0, .1, .5, .6). The next card is the array LSECT. This variable contains the number of sets of input points for each input plane. For the ring, 2 sets of input points for each input plane was chosen. Thus LSECT is equal to (2, 2). The next two cards are the array MSECT. This array contains the number of input points in each set of input points. The first line is for the bottom input plane. Here each set of input points will contain 4 points. The second line is for the top input plane. For this input plane, each set of input points will again have 4 input points. The last card contains the coordinates of an input point. The first 4 lines is for the first set of input points of the bottom input plane. Each line contains the coordinates of 1 input point. The next 4 lines are the coordinates of the input points of the second set of input points. The next 8 records are the input points of the top input plane.

CARD GROUP 28

The number of different material systems is 2. Each material system is represented by two records, thus four lines are required. The first record defines the location of the ply on the model by percent of thickness, length, and width. The first two values on this record refer to the initial and final percent thickness of the thickest grid point of the model. The next four values are the initial and final percent width and initial and final percent length. Since both plies are to be used over the entire shell, this record has the values 0.0, 100.0, 0.0, 100.0, 0.0, and 100.0. The second record specifies fiber type, matrix type, ply thickness, void volume ratio, fiber volume ratio, and orientation angle in degrees relative to the structural x-axis. Here both plies are identical, except for the ply thickness. The top and bottom plies are 0.05 in. thick, while all the other plies are 0.1 in. thick.

CARD GROUP 29

The ply stack-up order for the bottom half of the ring is designated by 4 plies starting at the bottom surface. This layup is in the array MPLY. MPLY is equal to (1, 2, 2, 2).

CARD GROUP 30

The ply stack-up order for the top half of the ring is designated by 3 plies starting at the top surface. This layup is in the array NPLY. NPLY is equal to (2, 2, 1).

CARD GROUP 32

The time at each load step is given in this card group.

CARD GROUP 39

This card group contains the information required for centrifugal loading. The first line defines the axis about which the structure is rotating. The second line contains the rotational velocity at each load step in revolutions per sec.

CARD GROUP 40

Since the TRANSFORMATION program option card was used, this group must be given. This card group provides for local coordinate transformation at various nodes. The first line consists of the variables IBEG, IEND, INCR, and IAXIS. Here IBEG is set to 4, IEND is set to 252, INCR is set to 4, and IAXIS (the axis about which the coordinates are to be transformed) is set to 1. IAXIS corresponds to the x-axis. The second line has the angle of rotation, which is 87.0 degrees.

CARD GROUP 41

This CARD GROUP contains the boundary condition data. Each record consist of the beginning node number, the ending node number, the node numbering increment, and the degree-of-freedom which is constrained. Note that for those nodes, which had their coordinate systems transformed, the degree-of-freedoms which are constrained will be in the transformed coordinate system.

CARD GROUP 42

This card group controls the output. Here the nodal displacements are desired at nodes 1 through 252. The ply stresses are desired at nodes 17, 89, 125, and 161. The constituent material properties and the constituent stresses of ply number 1 are needed at nodes 53 and 197.

INPUT DECK FOR PROBLEM #2

Note that the Card Group Nos. are not part of the input file

```
------------------ BLOCK #1   PROGRAM OPTION CARDS -----------------
TITLE=THICK RING SUBJECTED TO A CENTRIFUGAL LOADING
S3DSOLID MODEL OPTION
BRICK
PLYORDER
UNSYMMETRICAL
TRANSFORMATION
ANGULAR
ENDOPTION

------------------ BLOCK #2   CARD GROUPS --------------------------
CARD
GROUP
NO.
                 1         2         3         4         5         6         7
        1........0.........0.........0.........0.........0.........0.........0.

  1-     2
  4-     2    3    3    6
  6-     4
  7-     3
 10-     1    1    1    1   20   10
 10-        1.
 18-     1
 19-    11
 26-     2     .0
 26-     4     .1
 26-     2     .5
 26-           .6
 26-     2    2
 26-     4    4
 26-     4    4
 26-           .0         .0       2.875
 26-           .0        .05       2.875
 26-           .0         .1       2.873
 26-           .0       .151       2.871
 26-           .6         .0       2.875
 26-           .6        .05       2.875
 26-           .6         .1       2.873
 26-           .6       .151       2.871
```

CARD
GROUP
NO.

```
            1         2         3         4         5         6         7
    1.......0.........0.........0.........0.........0.........0.........0.

26-         .0        .0     3.475
26-         .0      .061     3.475
26-         .0      .121     3.473
26-         .0      .182      3.47
26-         .6        .0     3.475
26-         .6      .061     3.475
26-         .6      .121     3.473
26-         .6      .182      3.47
28-         .0      100.        .0      100.        .0      100.
28- SICA TI15        .05        .0       .35       90.
28-         .0      100.        .0      100.        .0      100.
28- SICA TI15         .1        .0       .35       90.
29-     1   2   2   2
30-     2   2   1
32-         .0
39-         .0        .0        .0        .6        .0        .0
39-      333.3
40-     4 252   4   1
40-        87.
41-    17 233  36   1
41-     1 217  36   2
41-     5 221  36   2
41-     9 225  36   2
41-    13 229  36   2
41-    17 233  36   2
41-    21 237  36   2
41-    25 241  36   2
41-    29 245  36   2
41-    33 249  36   2
41-     4 252   4   3
42-     1 252
42-    17  17  89  89 125 125 161 161
42-    53  53 197 197
42-     1   1
42-         .0
```

H I T C A N   O U T P U T   S U M M A R Y

THICK RING USING BRICK ELEMENT SUBJECTED TO A CENTRIFUGAL LOADING

INITIAL LOAD

PLY STRESSES (in psi. units) IN THE MATERIAL COORDINATE SYSTEM FOR NODE 17

PLY NO.	SIGL-11	SIGL-22	SIGL-33	SIGL-12	SIGL-23	SIGL-
1	0.184E+05	0.158E+02	0.000E+00	-0.920E-01	-0.480E+00	0.278

PLY STRESSES (in psi. units) IN THE MATERIAL COORDINATE SYSTEM FOR NODE 89

PLY NO.	SIGL-11	SIGL-22	SIGL-33	SIGL-12	SIGL-23	SIGL-
1	0.170E+05	0.530E+00	0.000E+00	0.320E+00	-0.945E+00	0.255

PLY STRESSES (in psi. units) IN THE MATERIAL COORDINATE SYSTEM FOR NODE 125

PLY NO.	SIGL-11	SIGL-22	SIGL-33	SIGL-12	SIGL-23	SIGL-
1	0.170E+05	0.960E-01	0.000E+00	0.380E-01	-0.195E+00	0.255E

PLY STRESSES (in psi. units) IN THE MATERIAL COORDINATE SYSTEM FOR NODE 161

PLY NO.	SIGL-11	SIGL-22	SIGL-33	SIGL-12	SIGL-23	SIGL-
1	0.160E+05	-0.210E+01	0.000E+00	0.380E+00	0.126E+00	0.255E

H I T C A N   O U T P U T   S U M M A R Y

THICK RING USING BRICK ELEMENT SUBJECTED TO A CENTRIFUGAL LOADING

DISPLACEMENTS AFTER THE INITIAL LOAD AT SELECTED NODES

NODE NO.	X (in.)	Y (in.)	Z (in.)
1	0.685E-04	0.228E-28	0.337E-02
2	0.683E-04	0.583E-04	0.337E-02
3	0.685E-04	0.118E-03	0.336E-02
4	0.684E-04	0.176E-03	0.336E-02
5	0.571E-04	0.457E-28	0.337E-02
6	0.569E-04	0.583E-04	0.337E-02
7	0.571E-04	0.118E-03	0.337E-02
8	0.569E-04	0.176E-03	0.336E-02
9	0.457E-04	0.686E-28	0.337E-02
10	0.455E-04	0.583E-04	0.337E-02
11	0.457E-04	0.118E-03	0.337E-02
12	0.455E-04	0.176E-03	0.336E-02
13	0.229E-04	0.915E-28	0.337E-02
14	0.227E-04	0.583E-04	0.337E-02
15	0.229E-04	0.118E-03	0.337E-02
16	0.227E-04	0.176E-03	0.336E-02
17	0.166E-31	0.914E-28	0.337E-02
18	-0.498E-07	0.584E-04	0.337E-02
19	0.714E-07	0.118E-03	0.337E-02
20	-0.162E-06	0.176E-03	0.336E-02
21	-0.227E-04	0.909E-28	0.337E-02
22	-0.229E-04	0.585E-04	0.337E-02
23	-0.227E-04	0.118E-03	0.337E-02
24	-0.230E-04	0.176E-03	0.336E-02
25	-0.455E-04	0.681E-28	0.337E-02
26	-0.458E-04	0.585E-04	0.337E-02
27	-0.454E-04	0.118E-03	0.337E-02
28	-0.457E-04	0.176E-03	0.336E-02
29	-0.569E-04	0.454E-28	0.337E-02
30	-0.573E-04	0.585E-04	0.337E-02

31	-0.568E-04	0.118E-03	0.337E-02
32	-0.570E-04	0.176E-03	0.336E-02
33	-0.684E-04	0.227E-28	0.337E-02
34	-0.687E-04	0.585E-04	0.337E-02
35	-0.682E-04	0.118E-03	0.336E-02
36	-0.683E-04	0.176E-03	0.336E-02
37	0.660E-04	0.448E-28	0.335E-02
38	0.662E-04	0.583E-04	0.335E-02
39	0.660E-04	0.117E-03	0.334E-02
40	0.662E-04	0.175E-03	0.334E-02
41	0.550E-04	0.895E-28	0.335E-02
42	0.552E-04	0.583E-04	0.335E-02
43	0.550E-04	0.117E-03	0.334E-02
44	0.552E-04	0.175E-03	0.334E-02
45	0.440E-04	0.134E-27	0.335E-02
46	0.442E-04	0.583E-04	0.335E-02
47	0.440E-04	0.117E-03	0.334E-02
48	0.442E-04	0.175E-03	0.334E-02
49	0.220E-04	0.179E-27	0.335E-02
50	0.221E-04	0.583E-04	0.335E-02
51	0.220E-04	0.117E-03	0.335E-02
52	0.221E-04	0.175E-03	0.334E-02
53	-0.196E-31	0.179E-27	0.335E-02
54	0.648E-07	0.584E-04	0.335E-02
55	-0.119E-06	0.117E-03	0.335E-02
56	0.806E-07	0.175E-03	0.334E-02
57	-0.222E-04	0.179E-27	0.335E-02
58	-0.219E-04	0.583E-04	0.335E-02
59	-0.222E-04	0.117E-03	0.335E-02
60	-0.219E-04	0.175E-03	0.334E-02
61	-0.443E-04	0.134E-27	0.335E-02
62	-0.439E-04	0.583E-04	0.335E-02
63	-0.443E-04	0.117E-03	0.334E-02
64	-0.439E-04	0.175E-03	0.334E-02
65	-0.553E-04	0.896E-28	0.335E-02
66	-0.549E-04	0.582E-04	0.335E-02
67	-0.553E-04	0.117E-03	0.334E-02
68	-0.550E-04	0.175E-03	0.334E-02
69	-0.663E-04	0.448E-28	0.335E-02
70	-0.659E-04	0.582E-04	0.335E-02
71	-0.663E-04	0.116E-03	0.334E-02
72	-0.660E-04	0.175E-03	0.334E-02
73	0.640E-04	0.431E-28	0.333E-02
74	0.638E-04	0.583E-04	0.333E-02
75	0.641E-04	0.117E-03	0.332E-02

76	0.638E-04	0.174E-03	0.332E-02
77	0.534E-04	0.863E-28	0.333E-02
78	0.532E-04	0.583E-04	0.333E-02
79	0.534E-04	0.117E-03	0.332E-02
80	0.532E-04	0.174E-03	0.332E-02
81	0.427E-04	0.129E-27	0.333E-02
82	0.425E-04	0.583E-04	0.333E-02
83	0.427E-04	0.117E-03	0.332E-02
84	0.425E-04	0.174E-03	0.332E-02
85	0.214E-04	0.173E-27	0.333E-02
86	0.212E-04	0.584E-04	0.333E-02
87	0.214E-04	0.117E-03	0.333E-02
88	0.212E-04	0.174E-03	0.332E-02
89	0.232E-31	0.173E-27	0.333E-02
90	-0.752E-07	0.584E-04	0.333E-02
91	0.952E-07	0.117E-03	0.333E-02
92	-0.126E-06	0.174E-03	0.332E-02
93	-0.212E-04	0.173E-27	0.333E-02
94	-0.214E-04	0.584E-04	0.333E-02
95	-0.212E-04	0.117E-03	0.333E-02
96	-0.215E-04	0.174E-03	0.332E-02
97	-0.425E-04	0.129E-27	0.333E-02
98	-0.428E-04	0.583E-04	0.333E-02
99	-0.425E-04	0.117E-03	0.332E-02
100	-0.428E-04	0.174E-03	0.332E-02
101	-0.531E-04	0.863E-28	0.333E-02
102	-0.534E-04	0.583E-04	0.333E-02
103	-0.531E-04	0.117E-03	0.332E-02
104	-0.535E-04	0.174E-03	0.332E-02
105	-0.637E-04	0.431E-28	0.333E-02
106	-0.641E-04	0.583E-04	0.333E-02
107	-0.638E-04	0.117E-03	0.332E-02
108	-0.641E-04	0.174E-03	0.332E-02
109	0.615E-04	0.416E-28	0.331E-02
110	0.618E-04	0.582E-04	0.331E-02
111	0.616E-04	0.115E-03	0.330E-02
112	0.619E-04	0.173E-03	0.330E-02
113	0.513E-04	0.831E-28	0.331E-02
114	0.515E-04	0.582E-04	0.331E-02
115	0.513E-04	0.116E-03	0.330E-02

116	0.516E-04	0.173E-03	0.330E-02
117	0.410E-04	0.125E-27	0.331E-02
118	0.412E-04	0.583E-04	0.331E-02
119	0.410E-04	0.116E-03	0.331E-02
120	0.412E-04	0.173E-03	0.330E-02
121	0.205E-04	0.166E-27	0.331E-02
122	0.206E-04	0.583E-04	0.331E-02
123	0.204E-04	0.116E-03	0.331E-02
124	0.207E-04	0.173E-03	0.330E-02
125	-0.309E-31	0.166E-27	0.331E-02
126	0.648E-07	0.583E-04	0.331E-02
127	-0.115E-06	0.116E-03	0.331E-02
128	0.118E-06	0.173E-03	0.330E-02
129	-0.207E-04	0.166E-27	0.331E-02
130	-0.204E-04	0.583E-04	0.331E-02
131	-0.207E-04	0.116E-03	0.331E-02
132	-0.204E-04	0.173E-03	0.330E-02
133	-0.413E-04	0.125E-27	0.331E-02
134	-0.409E-04	0.583E-04	0.331E-02
135	-0.413E-04	0.116E-03	0.331E-02
136	-0.410E-04	0.173E-03	0.330E-02
137	-0.516E-04	0.831E-28	0.331E-02
138	-0.512E-04	0.582E-04	0.331E-02
139	-0.516E-04	0.116E-03	0.330E-02
140	-0.513E-04	0.173E-03	0.330E-02
141	-0.618E-04	0.416E-28	0.331E-02
142	-0.615E-04	0.582E-04	0.331E-02
143	-0.619E-04	0.115E-03	0.330E-02
144	-0.616E-04	0.173E-03	0.330E-02
145	0.594E-04	0.400E-28	0.329E-02
146	0.592E-04	0.570E-04	0.329E-02
147	0.594E-04	0.114E-03	0.328E-02
148	0.591E-04	0.172E-03	0.328E-02
149	0.495E-04	0.799E-28	0.329E-02
150	0.493E-04	0.570E-04	0.329E-02
151	0.495E-04	0.114E-03	0.329E-02
152	0.493E-04	0.172E-03	0.328E-02
153	0.396E-04	0.120E-27	0.329E-02
154	0.394E-04	0.570E-04	0.329E-02
155	0.396E-04	0.114E-03	0.329E-02
156	0.394E-04	0.172E-03	0.328E-02
157	0.198E-04	0.160E-27	0.329E-02
158	0.197E-04	0.570E-04	0.329E-02
159	0.199E-04	0.114E-03	0.329E-02
160	0.196E-04	0.172E-03	0.328E-02

161	0.229E-31	0.160E-27	0.329E-02
162	-0.754E-07	0.570E-04	0.329E-02
163	0.108E-06	0.114E-03	0.329E-02
164	-0.133E-06	0.172E-03	0.328E-02
165	-0.197E-04	0.160E-27	0.329E-02
166	-0.199E-04	0.570E-04	0.329E-02
167	-0.196E-04	0.114E-03	0.329E-02
168	-0.199E-04	0.172E-03	0.328E-02
169	-0.394E-04	0.120E-27	0.329E-02
170	-0.397E-04	0.570E-04	0.329E-02
171	-0.394E-04	0.114E-03	0.329E-02
172	-0.397E-04	0.172E-03	0.328E-02
173	-0.492E-04	0.799E-28	0.329E-02
174	-0.496E-04	0.570E-04	0.329E-02
175	-0.492E-04	0.114E-03	0.329E-02
176	-0.496E-04	0.172E-03	0.328E-02
177	-0.591E-04	0.400E-28	0.329E-02
178	-0.595E-04	0.570E-04	0.329E-02
179	-0.591E-04	0.114E-03	0.328E-02
180	-0.594E-04	0.172E-03	0.328E-02
181	0.568E-04	0.386E-28	0.327E-02
182	0.570E-04	0.568E-04	0.327E-02
183	0.568E-04	0.114E-03	0.327E-02
184	0.570E-04	0.171E-03	0.326E-02
185	0.473E-04	0.771E-28	0.327E-02
186	0.475E-04	0.569E-04	0.327E-02
187	0.473E-04	0.114E-03	0.327E-02
188	0.476E-04	0.171E-03	0.326E-02
189	0.379E-04	0.116E-27	0.327E-02
190	0.380E-04	0.569E-04	0.327E-02
191	0.378E-04	0.114E-03	0.327E-02
192	0.381E-04	0.171E-03	0.326E-02
193	0.189E-04	0.154E-27	0.328E-02
194	0.191E-04	0.569E-04	0.327E-02
195	0.189E-04	0.114E-03	0.327E-02
196	0.191E-04	0.171E-03	0.326E-02
197	-0.284E-31	0.154E-27	0.328E-02
198	0.681E-07	0.569E-04	0.327E-02
199	-0.123E-06	0.114E-03	0.327E-02
200	0.128E-06	0.171E-03	0.326E-02
201	-0.191E-04	0.154E-27	0.328E-02
202	-0.189E-04	0.569E-04	0.327E-02
203	-0.191E-04	0.114E-03	0.327E-02
204	-0.188E-04	0.171E-03	0.326E-02
205	-0.381E-04	0.116E-27	0.327E-02

206	-0.378E-04	0.569E-04	0.327E-02
207	-0.381E-04	0.114E-03	0.327E-02
208	-0.378E-04	0.171E-03	0.326E-02
209	-0.476E-04	0.771E-28	0.327E-02
210	-0.473E-04	0.569E-04	0.327E-02
211	-0.476E-04	0.114E-03	0.327E-02
212	-0.472E-04	0.171E-03	0.326E-02
213	-0.571E-04	0.386E-28	0.327E-02
214	-0.567E-04	0.568E-04	0.327E-02
215	-0.571E-04	0.114E-03	0.327E-02
216	-0.567E-04	0.171E-03	0.326E-02
217	0.549E-04	0.190E-28	0.325E-02
218	0.545E-04	0.573E-04	0.325E-02
219	0.546E-04	0.113E-03	0.325E-02
220	0.543E-04	0.170E-03	0.324E-02
221	0.457E-04	0.381E-28	0.325E-02
222	0.454E-04	0.573E-04	0.325E-02
223	0.456E-04	0.113E-03	0.325E-02
224	0.452E-04	0.170E-03	0.324E-02
225	0.366E-04	0.571E-28	0.326E-02
226	0.363E-04	0.573E-04	0.325E-02
227	0.365E-04	0.113E-03	0.325E-02
228	0.362E-04	0.170E-03	0.324E-02
229	0.183E-04	0.762E-28	0.326E-02
230	0.181E-04	0.574E-04	0.326E-02
231	0.183E-04	0.113E-03	0.325E-02
232	0.180E-04	0.170E-03	0.324E-02
233	0.161E-31	0.762E-28	0.326E-02
234	-0.649E-07	0.574E-04	0.326E-02
235	0.111E-06	0.113E-03	0.325E-02
236	-0.174E-06	0.170E-03	0.324E-02
237	-0.181E-04	0.762E-28	0.326E-02
238	-0.183E-04	0.574E-04	0.326E-02
239	-0.181E-04	0.113E-03	0.325E-02
240	-0.184E-04	0.170E-03	0.324E-02
241	-0.363E-04	0.571E-28	0.326E-02
242	-0.366E-04	0.573E-04	0.325E-02
243	-0.362E-04	0.113E-03	0.325E-02
244	-0.366E-04	0.170E-03	0.324E-02
245	-0.454E-04	0.381E-28	0.325E-02
246	-0.457E-04	0.573E-04	0.325E-02
247	-0.453E-04	0.113E-03	0.325E-02
248	-0.457E-04	0.170E-03	0.324E-02
249	-0.546E-04	0.190E-28	0.325E-02
250	-0.548E-04	0.573E-04	0.325E-02
251	-0.543E-04	0.113E-03	0.325E-02
252	-0.547E-04	0.170E-03	0.324E-02

EXAMPLE PROBLEM #3

Example #3 demonstrates the basic characteristics of a dataset required to run the HPLATE model option in the HITCAN code. This example is of a modal analysis of a hollow built-up structure. The structure has 0.5 in. length, 0.2 in. width , 0.075 in. total thickness, 0.02 in. thickness at the top plate, 0.01 in. thickness of the bottom plate, and 3 spars in the x-z plane equally spaced in the y-direction with 0.02 in. thickness. The structure is made of Sic/Ti-15-3-3-3 composite material (Silicon Carbide fiber, Titanium matrix with 15% Vanadium, 3% Aluminum, 3% Chromium, and 3% Tin, and interphase with average properties of the fiber and the matrix). The composite laminate consists of 4 plies (90/0/0/90) of equal thickness for the top plate, 2 plies (90/90) of equal thickness for the bottom plate, and 4 plies (0/0/0/0) of equal thickness for the spars. Each ply has a fiber volume ratio of 0.5. See Figure 6.6 for a complete description of the geometry, boundary conditions, and the loading. Figure 6.7 illustrates the ply layup. The finite element model is shown in Figures 6.8 and 6.9. A portion of the output is shown after a discussion of the input deck.

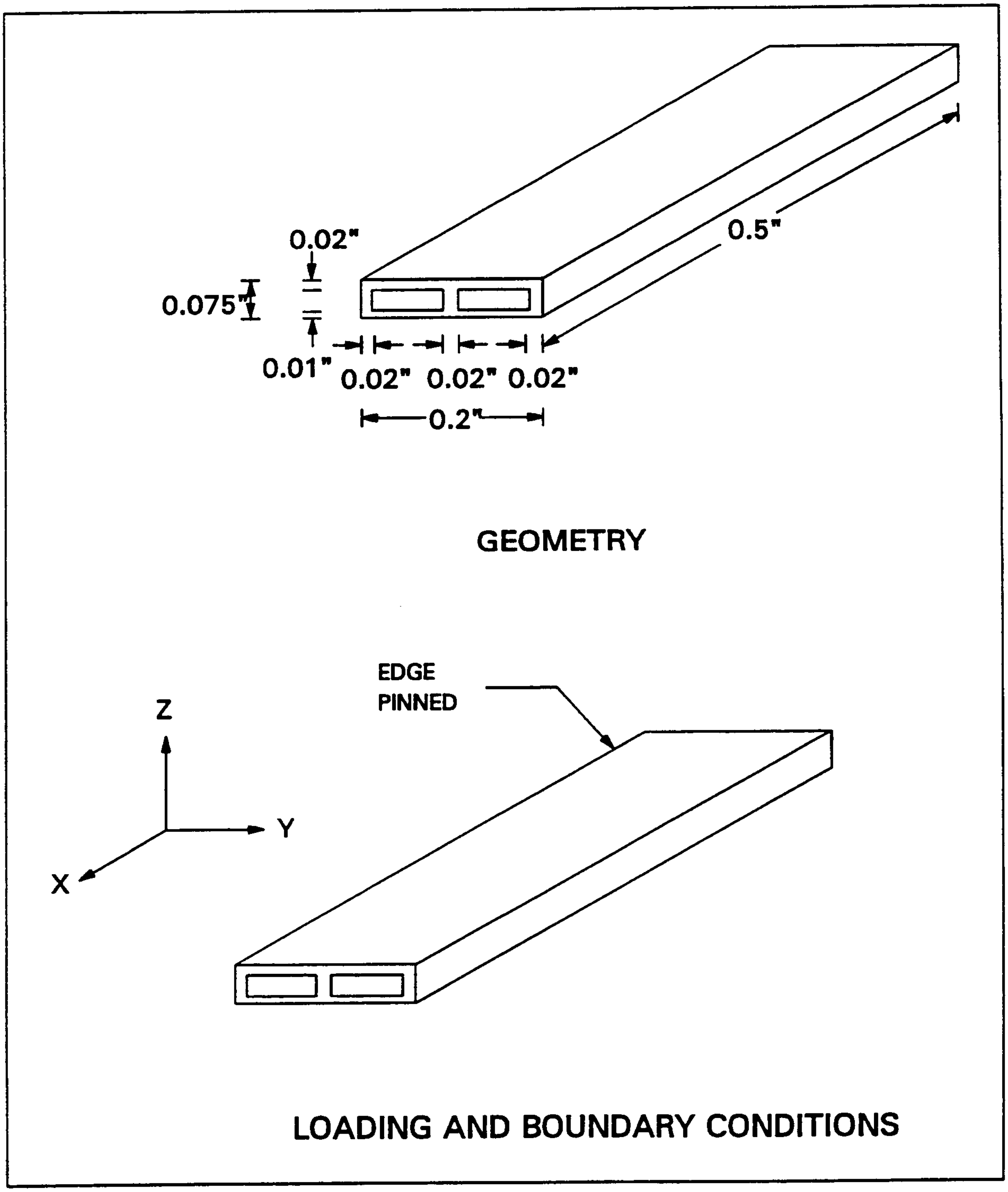

Figure 6.6: Examples Of Problem Number 3

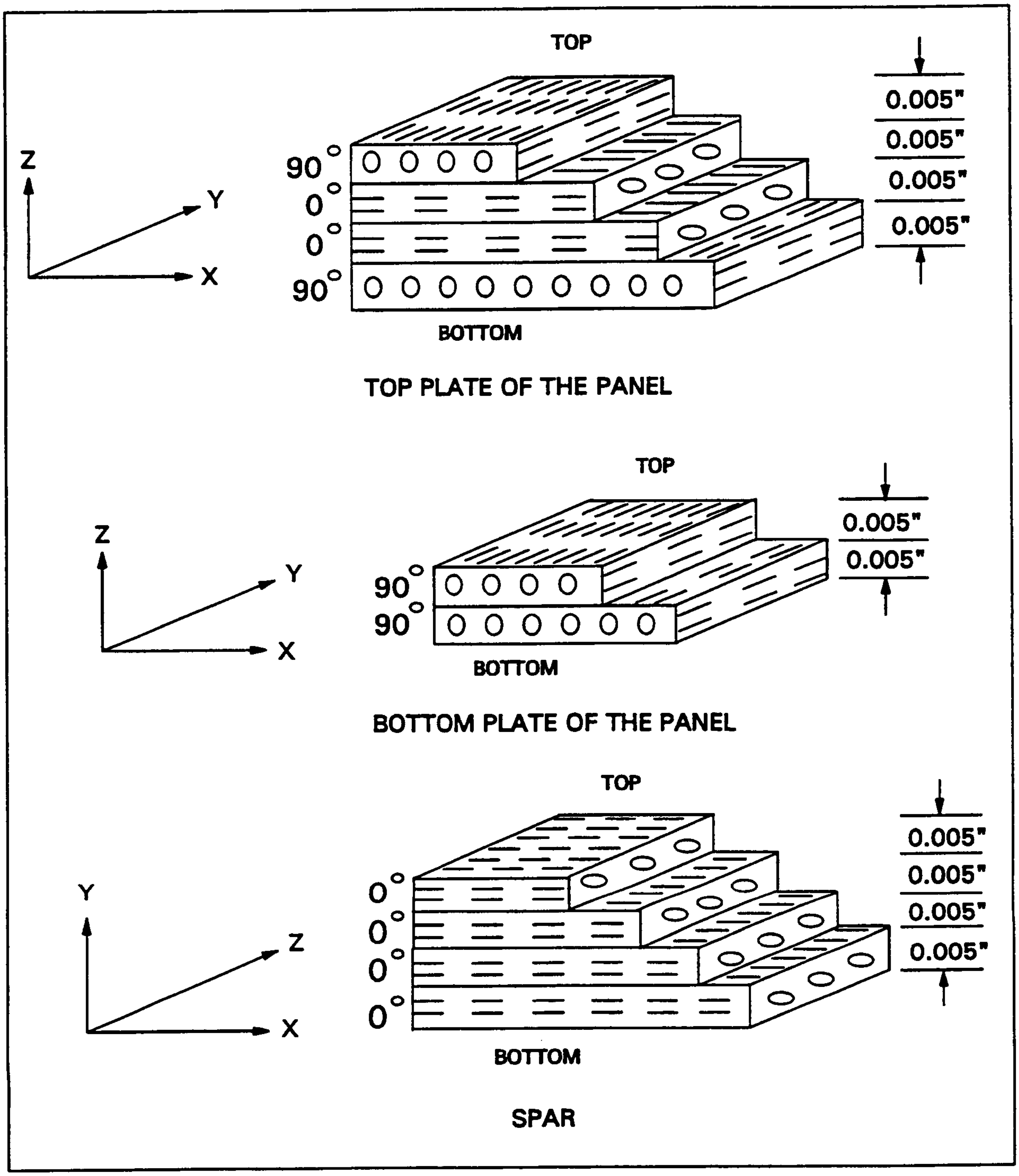

Figure 6.7: Ply Layup

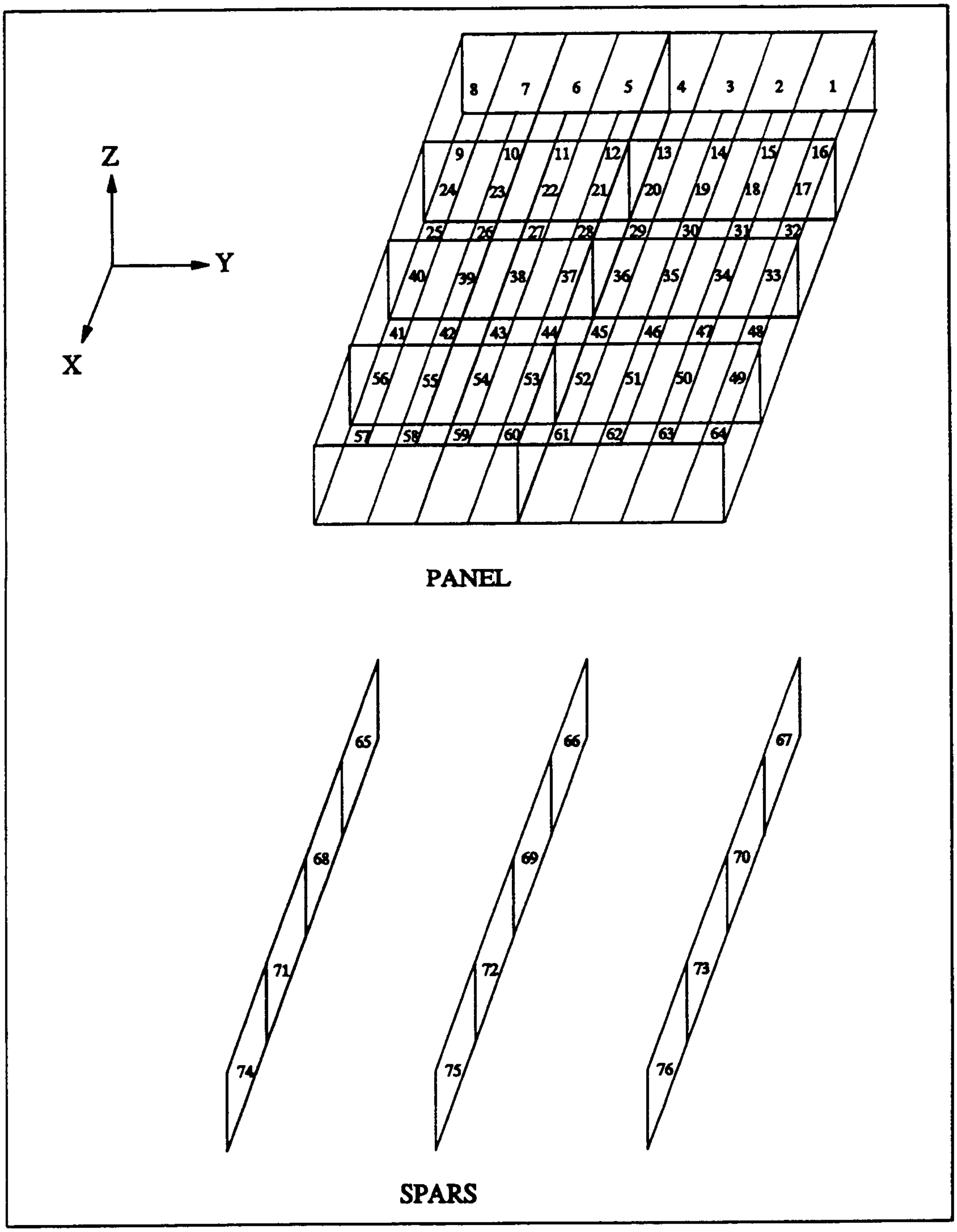

Figure 6.8: Finite Element Model Showing Element Numbers

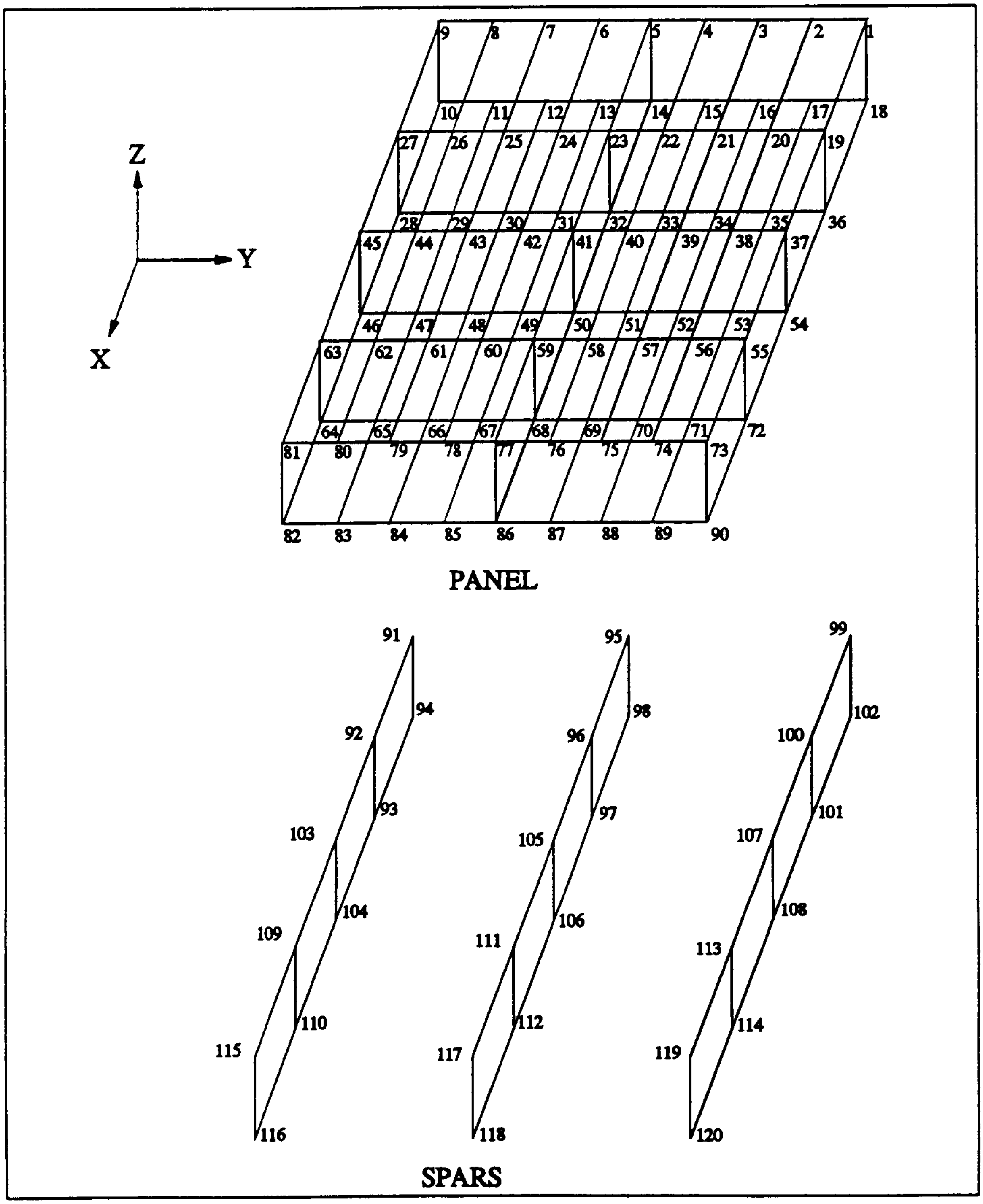

Figure 6.9: Finite Element Showing Node Numbers

INPUT DECK DESCRIPTION

PROGRAM OPTION CARDS

The program option cards chosen are:

TITLE
HPLATE
PANEL
PLATE
PROFILE
PLYORDER
MODAL
FORCE
ENDOPTION

CARD GROUP 1

The number of material systems to be described in Card Group 28 of this input deck is 2. One material system is required for the ply with a fiber orientation angle of 0°, another material system is required for the ply with a fiber orientation angle of 90°.

CARD GROUP 2

The number of output sections (NOSC) was chosen to be 2. Both of the output sections are to have spars, so the variable NXSPAR is set to 2. The number of spars was chosen to be 3. Since NYSPC is equal to 7, the number of elements along the
y-axis will be 8.

CARD GROUP 6

The number of plies for one-half of the wall thickness (MAXPLY) is set to 2. This means that the maximum number of plies available to fill the wall thickness is 4.

CARD GROUP 9

The first value on this line is the number of input cross sections on the top surface. The second value is the number of input cross sections on the bottom surface. Thus, the array LSECT has the values (3, 3).

CARD GROUP 10

In the this card group the number of load steps (NTISTP) is set to 1, the number of mechanical cycles (NMECHC) is set to 1, and the number of thermal cycles (NTHERC) is also set to 1. The number of load increments (LINC) between load steps is 1. Since a restart file is not desired, the variable MSTART is set to 20. The variable MITER, the maximum number of iterations allowed for global convergence, is set to 10. The tolerance on global convergence (TOL) is set to 1.0.

CARD GROUP 11

Since a modal analysis is desired this card group must be used. NEIGV is set to 1. INCREG is set to 0 card and MHITER is set to 20.

CARD GROUP 19

The number of boundary condition data sets (NBC) is 5.

CARD GROUP 24

In this card group the number of elements between output sections, the x-coordinate of the output sections, and the spar descriptions are given. The first line in this card group contains the ply designation numbers for the spars. This is the array NSPDES. Here this array has the values (1, 1, 1). The next line has the number of elements between output sections 1 and 2 and the x-coordinate of output section 1. The following line describes the 3 spars. Note that since the program option card PANEL was specified, the location of the spars is not needed. HITCAN will automatically place the spars at each end of the panel. In this example each spar has a wall thickness of 0.02 in. The array NXSPC will be equal to (2, 2). The x-coordinate of each output section is in the array X. This array has the values (.0, .25, .5). The next card is the number of points for each input cross section on the top surface. Each input cross section will have 3 input points. The next card contains this same information, but for the bottom of the panel. Here again 3 input points will be used for each input cross section. The next card contains the coordinates of an input point. The first 9 lines is for the input points of the top of the panel. The first 3 lines are for the first cross section. The next 3 lines are for the second cross section, etc. Each line contains the coordinates and wall thickness of 1 input point. The next 9 lines are the coordinates of the input points of the bottom of the panel.

CARD GROUP 28

The number of different material systems is 2. Each material system is represented by two records, thus four lines are required. The first record defines the location of the ply on the model by percent of thickness, length, and width. The first two values on this record refer to the initial and final percent thickness of the thickest grid point of the model. The next four values are the initial and final percent width and initial and final percent length. Since both plies are to be used over the entire shell, this record has the values 0.0, 100.0, 0.0, 100.0, 0.0, and 100.0. The second record specifies fiber type, matrix type, ply thickness, void volume ratio, fiber volume ratio, and orientation angle in degrees relative to the structural x-axis. Both plies are identical, except for the ply orientation.

CARD GROUP 29

The ply stack-up order for one-half of the wall thickness is designated by 2 plies starting at the bottom of the top surface. This layup is in the array MPLY. MPLY is equal to
(2, 1).

CARD GROUP 32

The time at each load step is given in this card group.

CARD GROUP 36

This card group contains the information required for concentrated force loading. The first line contains the node number and the direction of the applied force. The second line contains the value of the force at each load step.

CARD GROUP 41

This CARD GROUP contains the boundary conditions. Each record consists of the beginning node number, the ending node number, the node numbering increment, and the degree-of-freedom which is constrained.

CARD GROUP 42

This card group controls the output. Since the output controlled by this card is not desired, the cards in this group are blank.

CARD GROUP 44

Since a buckling analysis is desired the last card must contain the time at which the analysis is to be done.

INPUT DECK FOR PROBLEM #3

Note that the Card Group Nos. are not part of the Input File.

```
    ------------------ BLOCK #1   PROGRAM OPTION CARDS -----------------
    TITLE-BUCKLING ANALYSIS OF A PANEL SUBJECTED TO A NODAL FORCES
    HPLATE MODEL OPTION
    PANEL
    PLATE
    PROFILE
    PLYORDER
    MODAL
    FORCE
    ENDOPTION

    ------------------ BLOCK #2   CARD GROUPS -------------------------
CARD
GROUP
NO.

             1         2         3         4         5         6         7
    1........0.........0.........0.........0.........0.........0.........0.

 1-    2
 2-    2   2   3   7
 6-    2
 9-    3   3
10-    1   1   1   1  20  10
10-       1.
11-    1   0  20
15-   10
19-    5
24-    1   1   1
24-    2    .0
24-         .0       .02        .0       .02        .0       .02
24-    2   .25
24-         .0       .02        .0       .02        .0       .02
24-         .5
24-         .0       .02        .0       .02        .0       .02
24-    3   3   3
24-    3   3   3
24-         .0       -.1       .04       .02
24-         .0        .0       .04       .02
24-         .0        .1       .04       .02
24-        .25       -.1       .04       .02
24-        .25        .0       .04       .02
```

```
CARD
GROUP
NO.
             1         2         3         4         5         6         7
    1........0.........0.........0.........0.........0.........0.........0.

24-        .25        .1       .04       .02
24-         .5       -.1       .04       .02
24-         .5        .0       .04       .02
24-         .5        .1       .04       .02
24-         .0       -.1      .035       .01
24-         .0        .0      .035       .01
24-         .0        .1      .035       .01
24-        .25       -.1      .035       .01
24-        .25        .0      .035       .01
24-        .25        .1      .035       .01
24-         .5       -.1      .035       .01
24-         .5        .0      .035       .01
24-         .5        .1      .035       .01
28-         .0      100.        .0      100.        .0      100.
28- SICA TI15       .005        .0        .4        .0
28-         .0      100.        .0      100.        .0      100.
28- SICA TI15       .005        .0        .4       90.
41-    37  54   1   1
41-     9  81  18   2
41-    10  82  18   2
41-     9  81  18   3
41-    10  82  18   3
42-
42-
42-
42-
44-         .0
44-         .0
```

EIGENVALUE EXTRACTION

EIGENVALUE NUMBER 1 VALUE = 0.417307E+11

FREQUENCY IN RADIANS PER TIME= 2.04281E+05
IN CYCLES PER TIME= 3.25123E+04

EIGENVECTOR

1	-0.44068E-04	-0.50138E-03	0.19879E-01	0.44014E-01	0.65224E-02	-0.14355E-02
2	-0.64371E-04	-0.47639E-03	0.18613E-01	0.74422E-01	0.10572E-01	-0.16626E-03
3	-0.74521E-04	-0.45013E-03	0.16127E-01	0.92105E-01	0.36837E-02	-0.15163E-02
4	-0.84008E-04	-0.42292E-03	0.13719E-01	0.92864E-01	-0.42625E-02	0.52418E-03
5	-0.10170E-03	-0.39471E-03	0.11458E-01	0.73225E-01	0.84235E-03	-0.25777E-02
6	-0.13377E-03	-0.29861E-03	0.90688E-02	0.11862	0.10538E-01	0.78445E-03
7	-0.13573E-03	-0.20165E-03	0.55557E-02	0.13178	-0.35609E-02	-0.17282E-02
8	-0.11960E-03	-0.10259E-03	0.18931E-02	0.11079	-0.18373E-01	0.26041E-02
9	-0.74056E-04	0.00000	0.00000	0.55115E-01	-0.10605E-01	-0.13194E-02
10	0.62265E-04	0.00000	0.00000	-0.40915E-01	-0.37307E-02	-0.27841E-02
11	0.16270E-03	0.17528E-03	0.49524E-03	0.13274	-0.51143E-01	-0.21433E-03
12	0.19633E-03	0.34636E-03	0.56153E-02	0.19121	-0.26804E-02	-0.26924E-02
13	0.18874E-03	0.51607E-03	0.10680E-01	0.13654	0.43970E-01	0.39203E-02
14	0.11658E-03	0.68713E-03	0.11474E-01	-0.23685E-01	-0.36070E-02	-0.29688E-02
15	0.11486E-03	0.72990E-03	0.12008E-01	0.97397E-01	-0.36080E-01	0.23159E-02
16	0.10741E-03	0.77407E-03	0.15596E-01	0.13321	-0.25701E-02	-0.29232E-02
17	0.94232E-04	0.81987E-03	0.19038E-01	0.95538E-01	0.26920E-01	0.25141E-02
18	0.65793E-04	0.86752E-03	0.19886E-01	-0.26750E-03	-0.15500E-02	-0.28859E-02
19	-0.31690E-04	-0.55153E-03	0.20821E-01	0.45063E-01	-0.47602E-02	0.75966E-03
20	-0.32693E-04	-0.52135E-03	0.18181E-01	0.75476E-01	-0.67225E-02	-0.55824E-03
21	-0.38870E-04	-0.49158E-03	0.16389E-01	0.93243E-01	-0.36696E-02	0.78288E-03
22	-0.45164E-04	-0.46260E-03	0.13853E-01	0.93888E-01	-0.14494E-03	-0.78824E-03
23	-0.46838E-04	-0.43400E-03	0.11685E-01	0.74514E-01	-0.26794E-02	0.12261E-02
24	-0.44147E-04	-0.32433E-03	0.88657E-02	0.12187	-0.68477E-02	-0.76703E-03
25	-0.42908E-04	-0.21411E-03	0.56421E-02	0.13625	0.27205E-03	0.18045E-02
26	-0.34395E-04	-0.10530E-03	0.27384E-02	0.11491	0.81257E-02	-0.61813E-03
27	-0.26688E-04	0.00000	0.00000	0.57908E-01	0.46249E-02	0.18159E-02
28	0.16035E-04	0.00000	0.00000	-0.40957E-01	0.14883E-02	0.85991E-03
29	0.19713E-04	0.16354E-03	0.22118E-02	0.13770	0.25099E-01	-0.11337E-02
30	0.33685E-04	0.33246E-03	0.56905E-02	0.19878	0.10003E-03	0.95395E-03

EXAMP43

31	0.39580E-04	0.50180E-03	0.93871E-02	0.14157	-0.23255E-01	-0.12885E-
32	0.55672E-04	0.66674E-03	0.11789E-01	-0.23172E-01	-0.86785E-03	0.12271E-
33	0.51856E-04	0.71579E-03	0.13316E-01	0.99097E-01	0.15558E-01	-0.62321E-
34	0.47448E-04	0.76332E-03	0.15788E-01	0.13592	-0.96052E-03	0.96939E-
35	0.42353E-04	0.80895E-03	0.18316E-01	0.97189E-01	-0.14830E-01	-0.42513E-
36	0.43371E-04	0.85167E-03	0.20830E-01	0.48100E-03	-0.11399E-02	0.69134E-
37	0.00000	-0.52836E-03	0.20890E-01	0.44346E-01	0.36426E-09	-0.96158E-1
38	0.00000	-0.50166E-03	0.18828E-01	0.73717E-01	-0.10804E-09	0.53725E-1
39	0.00000	-0.47327E-03	0.16372E-01	0.90609E-01	0.11798E-09	0.25481E-1
40	0.00000	-0.44262E-03	0.14001E-01	0.91897E-01	-0.15582E-09	0.48873E-1
41	0.00000	-0.41024E-03	0.11752E-01	0.73608E-01	0.42504E-09	-0.11537E-1
42	0.00000	-0.30811E-03	0.93164E-02	0.12076	-0.18976E-09	0.63182E-1
43	0.00000	-0.20586E-03	0.57329E-02	0.13433	0.11997E-09	-0.53351E-1
44	0.00000	-0.10325E-03	0.19849E-02	0.11406	-0.30404E-09	-0.15734E-1
45	0.00000	0.00000	0.00000	0.57606E-01	0.60376E-09	0.19579E-1
46	0.00000	0.00000	0.00000	-0.42344E-01	-0.96887E-09	0.15852E-1
47	0.00000	0.17158E-03	0.53280E-03	0.13621	0.63277E-09	0.18521E-1
48	0.00000	0.34152E-03	0.57445E-02	0.19429	-0.48616E-09	-0.16786E-1
49	0.00000	0.51269E-03	0.10838E-01	0.14078	0.62823E-09	0.12272E-1
50	0.00000	0.68758E-03	0.11775E-01	-0.23800E-01	-0.83257E-09	-0.89052E-1
51	0.00000	0.73373E-03	0.12313E-01	0.96722E-01	0.53419E-09	-0.29836E-1
52	0.00000	0.78030E-03	0.15858E-01	0.13051	-0.35826E-09	0.40215E-1
53	0.00000	0.82736E-03	0.19254E-01	0.94535E-01	0.48371E-09	0.16462E-1
54	0.00000	0.87578E-03	0.20897E-01	0.39960E-03	-0.49452E-09	0.36314E-1
55	0.31690E-04	-0.55153E-03	0.20821E-01	0.45063E-01	0.47602E-02	-0.75966E-0
56	0.32693E-04	-0.52135E-03	0.18181E-01	0.75476E-01	0.67225E-02	0.55824E-0
57	0.38870E-04	-0.49158E-03	0.16309E-01	0.93243E-01	0.36696E-02	-0.70288E-0
58	0.45164E-04	-0.46260E-03	0.13853E-01	0.93888E-01	0.14494E-03	0.78824E-0
59	0.46838E-04	-0.43400E-03	0.11685E-01	0.74514E-01	0.26794E-02	-0.12261E-0
60	0.44147E-04	-0.32433E-03	0.88657E-02	0.12187	0.68477E-02	0.76783E-0
61	0.42908E-04	-0.21411E-03	0.56421E-02	0.13625	-0.27205E-03	-0.18845E-0
62	0.34395E-04	-0.10530E-03	0.27384E-02	0.11491	-0.81257E-02	0.61815E-0
63	0.26688E-04	0.00000	0.00000	0.57908E-01	-0.46249E-02	-0.18159E-0
64	-0.16035E-04	0.00000	0.00000	-0.40957E-01	-0.14883E-02	-0.85991E-0
65	-0.19713E-04	0.16354E-03	0.22118E-02	0.13770	-0.25099E-01	0.11337E-0
66	-0.33685E-04	0.33246E-03	0.56905E-02	0.19878	-0.10084E-03	-0.93395E-0
67	-0.39580E-04	0.50180E-03	0.93871E-02	0.14157	0.23255E-01	0.12885E-02
68	-0.55672E-04	0.66674E-03	0.11789E-01	-0.23172E-01	0.86784E-03	-0.12271E-02
69	-0.51856E-04	0.71579E-03	0.13316E-01	0.99097E-01	-0.15558E-01	0.62321E-03
70	-0.47448E-04	0.76332E-03	0.15788E-01	0.13592	0.96052E-03	-0.96939E-03
71	-0.42353E-04	0.80895E-03	0.18316E-01	0.97189E-01	0.14830E-01	0.42513E-03
72	-0.43377E-04	0.85167E-03	0.20830E-01	0.48100E-03	0.11399E-02	-0.69134E-03
73	0.44 E-04	-0.50138E-03	0.19879E-01	0.44014E-01	-0.65224E-02	0.14355E-02
74	0.64 E-04	-0.47639E-03	0.18613E-01	0.74422E-01	-0.10572E-01	0.16626E-03
75	0.74 1E-04	-0.45013E-03	0.16127E-01	0.92105E-01	-0.36837E-02	0.15163E-02

EXAMP44

76	0.84008E-04	-0.42292E-03	0.13719E-01	0.92864E-01	0.42625E-02	-0.52418E-03
77	0.18170E-03	-0.39471E-03	0.11458E-01	0.73225E-01	-0.84235E-03	0.23777E-02
78	0.13377E-03	-0.29861E-03	0.98688E-02	0.11862	-0.18538E-01	-0.78445E-03
79	0.13573E-03	-0.28165E-03	0.55557E-02	0.13178	0.35609E-02	0.17282E-02
80	0.11960E-03	-0.18259E-03	0.18931E-02	0.11879	0.18373E-01	-0.26041E-02
81	0.74056E-04	0.00000	0.00000	0.55115E-01	0.18685E-01	0.13194E-02
82	-0.62265E-04	0.00000	0.00000	-0.40915E-01	0.37387E-02	0.27841E-02
83	-0.16270E-03	0.17528E-03	0.49324E-03	0.13274	0.51143E-01	0.21453E-03
84	-0.19633E-03	0.34636E-03	0.56153E-02	0.19121	0.26804E-02	0.26924E-02
85	-0.18874E-03	0.51687E-03	0.18600E-01	0.13654	-0.43970E-01	-0.39283E-02
86	-0.11658E-03	0.68713E-03	0.11474E-01	-0.23685E-01	0.36078E-02	0.29688E-02
87	-0.11486E-03	0.72990E-03	0.12888E-01	0.97397E-01	0.36080E-01	-0.23159E-02
88	-0.18741E-03	0.77407E-03	0.15596E-01	0.13321	0.25701E-02	0.24232E-02
89	-0.94232E-04	0.81987E-03	0.19038E-01	0.95538E-01	-0.26920E-01	-0.25141E-02
90	-0.65793E-04	0.86752E-03	0.19886E-01	-0.26758E-03	0.15580E-02	0.28859E-02
91	-0.30407E-04	-0.73027E-05	-0.24703E-03	-0.11532E-03	-0.13208E-02	-0.13625E-04
92	-0.27349E-04	-0.72955E-05	-0.23944E-03	-0.49724E-03	-0.12975E-02	0.29355E-03
93	-0.22399E-04	-0.64103E-05	-0.22072E-03	-0.88415E-03	-0.11632E-02	-0.81536E-05
94	-0.19910E-04	-0.52383E-05	-0.19314E-03	-0.18617E-02	-0.90121E-03	0.22154E-03
95	-0.16270E-04	-0.42542E-05	-0.16492E-03	-0.83296E-03	-0.82145E-03	0.51788E-04
96	-0.12731E-04	-0.40853E-05	-0.13184E-03	-0.15481E-02	-0.75634E-03	0.23857E-03
97	-0.83718E-05	-0.31886E-05	-0.85123E-04	-0.18558E-02	-0.42603E-03	0.38632E-04
98	-0.49762E-05	-0.17885E-05	-0.36561E-04	-0.16498E-02	-0.58642E-04	0.11887E-03
99	-0.24870E-05	0.00000	0.00000	-0.86227E-03	0.99653E-04	0.88495E-04
100	0.31511E-05	0.00000	0.00000	0.55399E-03	0.46599E-03	0.45384E-04
101	0.77957E-05	0.19971E-05	-0.22994E-04	-0.28903E-02	0.26556E-03	-0.26225E-03
102	0.13750E-04	0.33270E-05	-0.87728E-04	-0.27884E-02	-0.43755E-03	-0.19361E-04
103	0.20838E-04	0.38991E-05	-0.14721E-03	-0.17363E-02	-0.11853E-02	-0.40803E-03
104	0.27226E-04	0.34647E-05	-0.16451E-03	0.57987E-03	-0.74308E-03	0.61493E-04
105	0.32891E-04	0.44933E-05	-0.17778E-03	-0.13251E-02	-0.49394E-03	-0.31191E-03
106	0.36157E-04	0.56506E-05	-0.21594E-03	-0.14637E-02	-0.11688E-02	0.17770E-04
107	0.41593E-04	0.64556E-05	-0.24331E-03	-0.60318E-03	-0.14485E-02	-0.35794E-03
108	0.45613E-04	0.63377E-05	-0.24662E-03	0.36661E-03	-0.13496E-02	0.51878E-04
109	-0.27756E-04	0.59126E-06	-0.18527E-03	-0.65348E-04	-0.88436E-03	-0.14911E-04
110	-0.19493E-04	0.15614E-05	-0.18328E-03	-0.19028E-03	-0.89115E-03	0.25897E-03
111	-0.15662E-04	0.21852E-05	-0.96762E-04	-0.36586E-03	-0.80228E-03	0.78398E-06
112	-0.13988E-04	0.26222E-05	-0.86455E-04	-0.47855E-03	-0.81689E-03	0.40466E-04
113	-0.15481E-04	0.30282E-05	-0.74815E-04	-0.42940E-03	-0.59600E-03	-0.45844E-04
114	-0.94626E-05	0.27414E-05	-0.59567E-04	-0.77164E-03	-0.39649E-03	0.19794E-03
115	-0.5988 -05	0.21286E-05	-0.37959E-04	-0.91199E-03	-0.33884E-03	0.86940E-06
116	-0.3544 -05	0.11923E-05	-0.15817E-04	-0.79945E-03	-0.23353E-03	0.93786E-04

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4. Hopkins, P.A., "Nonlinear Analysis for High-Temperature Multilayered Fiber Composite Structures", NASA TM-83754, 1984.

5. Hopkins, P.A. and Chamis, C.C., "A Unique Set of Micromechanics Equations for High Temperature Metal Matrix Composites", NASA TM-87154, 1985.

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4. TITLE AND SUBTITLE

High Temperature Composite Analyzer (HITCAN) User's Manual
Version 1.0

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WU-505-63-5B

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13. ABSTRACT ***(Maximum 200 words)***

This manual describes "how-to-use" the computer code, HITCAN (HIgh Temperature Composite ANalyzer). HITCAN is a general purpose computer program for predicting nonlinear global structural and local stress-strain response of arbitrarily oriented, multilayered high temperature metal matrix composite structures. This code combines composite mechanics and laminate theory with an internal data base for material properties of the constituents (matrix, fiber and interphase). The thermo-mechanical properties of the constituents are considered to be nonlinearly dependent on several parameters including temperature, stress and stress rate. The computation procedure for the analysis of the composite structures uses the finite element method. HITCAN is written in FORTRAN 77 computer language and at present has been configured and executed on the NASA Lewis Research Center CRAY XMP and YMP computers. This manual describes HITCAN's capabilities and limitations followed by input/execution/output descriptions and example problems. The input is described in detail including (1) geometry modeling, (2) types of finite elements, (3) types of analysis, (4) material data, (5) types of loading, (6) boundary conditions, (7) output control, (8) program options, and (9) data bank.

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